

Report for  
Waterways Experiment Station  
Contract # 96X3123 O+M General, CE  
(607-Y160.66YV6Q)

An Annotated Bibliography

on

The Duwamish River - Elliott Bay Complex

with

Special reference to biological  
effects of dredge disposal

by

Suanne Y. Smith and George Snyder

Environmental Conservation Division  
Northwest Fisheries Center  
National Marine Fisheries Service  
National Oceanic and Atmospheric Administration  
2725 Montlake Boulevard East  
Seattle, Washington 98112

May 1976



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## INTRODUCTION

This annotated bibliography was compiled for the Dredged Materials Research Program of the Waterways Experiment Station (WES) and relates to an on-going study of effects of the disposal of dredged material into Elliott Bay, selected marine organisms with special reference to the uptake of polychlorinated biphenyls (PCB's) and trace metals. This bibliography was prepared from current literature (since 1965) with a few exceptions for earlier pertinent work. No attempt was made to include foreign language publications or abstracts on dredge or disposal studies; Ellinger and Snyder (1965) recently completed an annotated bibliography of effects of dredging and dredge spoils on aquatic organisms in the Pacific Northwest. Furthermore, due to the large volume of information on other phases of the problem, such as methods of analysis, industrial uses, and earlier publications, the reader is referred to the bibliographies and selected reference material listed herein.

The bibliography is divided into seven sections. The first contains references on the physical descriptions of the Duwamish River - Elliott Bay complex such as circulation and mixing, sediment transport and water quality. Other references specifically concerned with biological communities in either the Duwamish River or Elliott Bay are also included here.

The second section contains information on the biological communities of benthic and pelagic organisms in Puget Sound and the Northeast Pacific Ocean. General references to the physical and chemical properties of Puget Sound are also included.

The occurrence of PCB's and certain trace metals (mercury and cadmium) in the environment and their effects on marine organisms form sections three and four. Since few publications exist on studies of the organisms used in the Elliott Bay study, uptake studies on closely related organisms were included. Other studies of interest may be found in the selected reference list.

Section five includes studies on the life histories of the invertebrates used in the Elliott Bay study. Also included are studies on the abundance and distribution of these invertebrates in Puget Sound. Parastichopus californicus used as a test organism for uptake studies in Elliott Bay lacks published descriptions of general distribution and life history and the reader is therefore referred to general texts for this information.

The sixth section contains studies on the life histories, abundance and distribution in the Pacific Northwest of the finfish selected for this study. Studies on their behavior and migration patterns are also included.

An annotated list of selected bibliographies and literature reviews since 1970 form the seventh section.

The supplementary reference list (not annotated) includes those articles that did not fit into the above categories and related studies done in other parts of the world.

## BACKGROUND REFERENCES ON THE DUWAMISH RIVER—ELLIOTT BAY COMPLEX

CH2M/Hill. Ongoing research. Duwamish Estuary Study. For, Municipality of Metropolitan Seattle, In: 1974 A Compendium of Current Environmental studies in Puget Sound and Northwest Estuarine Waters.

A computer model was developed by CH2M/Hill for the Municipality of Metropolitan Seattle (METRO) to simulate the hydrodynamics and water quality of the upper Duwamish River Estuary. The model was specifically designed to investigate the effects of future increases in discharge from the Renton Treatment Plant on water quality in the estuary.

Model structure consisted of two components: (1) hydrodynamics; and (2) quality. The hydrodynamic model, an adaptation of a U.S. Geological Survey program, simulated transient river and tidal flows found in the Duwamish Estuary through the use of a homogeneous one-dimensional flow system. The quality model simulated the physical, chemical and biological reactions taking place within the estuary. Twenty-six water quality parameters including temperature, DO, BOD, various nitrogen and phosphorous forms, phytoplankton, and the carbon cycle were simulated.

Hourly water quality input was required at both the head and the mouth of the estuary. A meteorologic data base consisting of daily values of air temperature, solar radiation, evaporation, dew point, etc., was also required. Subroutines within the model distributed the daily data over the day for hourly simulation. In addition, a total of five continuous point source discharges was allowed.

The hydrodynamic and quality models were calibrated to 1972 observed data. Following calibration, the models were used to simulate water quality for a 1-in-10-year, low-flow period which occurred in 1967. Current treatment plant flows (35 cfs) and land use patterns of the Green-Duwamish River drainage basin were incorporated into the model. To evaluate the year 2000 water quality, simulations utilizing projected treatment plant flows of 123 cfs and future land use characteristics were compared to the 1967 simulations. The only major changes observed were two-fold increases in  $PO_4$ ,  $NH_3$ , and  $NO_3$  concentrations. Phytoplankton blooms did not increase substantially, suggesting that nutrients were not the only limiting factors in this system.

### Shortened Author's Abstract

Dawson, W.A. and L.J. Tilley. 1968. Measurement of Salt-Wedge Excursion Distance in the Duwamish River Estuary, Seattle, Washington, by Means of the Dissolved-Oxygen Gradient. U.S. Geological Survey Water-Supply Paper. 1873-D, 27 pp.

The Duwamish River estuary has been the object of a series of comprehensive studies undertaken to predict the effects of the changing character of waste-water inputs on the water quality of the estuary. This report discusses the fresh- and salt-water relations of the estuary. The distance that the salt-water wedge in the estuary moves upstream and downstream with the tide is measured by a method that utilizes the persistence of the longitudinal gradient of dissolved oxygen in the salt water of the wedges. The method, though unorthodox, can serve as an independent check on any other measurements of tidal-excursion distance. Typical values obtained were a 1-kilometer excursion for a 1.3-meter tide range and a 3-kilometer excursion for a 3-meter tide range. This method of tracing the water movement seems to work because of two unusual aspects of the Duwamish River estuary: (1) the channel configuration is simple and well-suited to synoptic measurement and (2) the physical properties of the entering salt water are nearly constant.

#### Author's Abstract

Edmonson, S.A. 1973. Sediment transport in the Duwamish Estuary (Seattle). M.S. Thesis, University of Washington, Department of Civil Engineering, Seattle.

The objective of this study was to determine the quality of sediment being transported into, retained by, and out of the Duwamish Estuary for a given average monthly inflow of freshwater in the Green River at the U.S. Geological Survey gaging station at Auburn, Washington.

Fischer, H.B. 1975. Description of the Model, Part I of A Numerical model of material transport in salt-wedge estuaries. U.S. Geological Survey Prof. Paper. 917: 1-8.

Water in a salt-wedge estuary ideally is characterized by an oscillating well-mixed wedge of undiluted seawater topped by a series of successively more dilute overlying layers. In the wedge the flow is back and forth, with a net landward component to replace water entrained upward into the overlying layer; in the overlying layers the flow also oscillates, but with a net seaward component because of the input of fresh river water and entrained wedge water. The flow is modeled by a computer program, and the flow is used as an input to the constituent-transport model. The computer program then is used to determine the advection and dispersion of dissolved constituents and plankton, and their concentrations throughout the system in response to given inputs. The report describes required input data and method of operation of the computer program.

#### Author's Abstract

Fischer, H.B. 1968. Methods for Predicting Dispersion Coefficients in Natural Streams, with Applications to Lower Reaches of the Green and Duwamish Rivers, Washington. U.S. Geological Survey Prof. Paper. 582-A, 27 pp.

Four dye dispersion experiments were conducted in the Green and Duwamish Rivers, Wash. Longitudinal dispersion coefficients were obtained in two experiments, lateral concentration variations in the third, and aerial photographs in the fourth. The study reach was a section of meandering river, most of which is affected by tides during a part of the tidal cycle. Dispersion was observed during normal riverflow and tidal reversals. In normal flow of about 300 cfs the observed dispersion coefficient was 70-90 ft<sup>2</sup> per sec.

In natural riverflow, lateral variation in velocity is hypothesized to be the dominant mechanism for dispersion. With this hypothesis, G.I. Taylor's theory for turbulent dispersion in pipes may be applied to natural streamflow. The resulting analysis predicts a dispersion coefficient of 88 ft<sup>2</sup> per sec for a flow of 300 cfs in the Green and Duwamish Rivers.

A numerical solution to the convective diffusion equation is obtained, utilizing a high-speed electronic computer. Analysis of a two-dimensional flow with logarithmic velocity profile, for which a theoretical result is available, shows that the program produces accurate results. Analysis of the flow in the Green and Duwamish Rivers predicts a dispersion coefficient of 91 ft<sup>2</sup> per sec.

The analyses herein presented, both analytical and numerical, provide two ways of predicting a dispersion coefficient for a natural stream. The prediction requires field measurement of channel geometry, shear stress, and cross-sectional distribution of velocity only. Hopefully, future field experiments will further confirm the two prediction methods.

#### Author's Abstract

Gibbs, C.V. and G.W. Isaac. 1968. Metropolitan Seattle's Duwamish Estuary Water Quality Program. Journal Water Pollution Control Federation, 40: 385-394.

This paper describes the METRO monitoring program on the Duwamish Estuary. The program was established to safeguard the river and its estuary from possible deleterious effects from the Renton Treatment Plant. Included are descriptions of the diurnal, profile, and biological studies being carried out.

Haushild, W.L. and E.A. Prych. Ongoing research. The influence of Industrial and Municipal Wastes on Estuarine and Offshore Waters. For, U.S. Geological Survey, in: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

The study determines the effects of changes (made through the comprehensive sewerage plan of the Municipality of Metropolitan Seattle, METRO), in the quality and quantity of municipal and industrial wastes on the quality of the receiving waters, the Duwamish River estuary and Puget Sound. Included in the study are the effects of changes in: (1) degree and type of waste treatment; (2) quantity of treated and untreated waste effluents; (3) geometry of the Duwamish estuary through proposed widening and deepening of ship and barge channels; and (4) quality of the waters flowing into the Duwamish estuary from Elliott Bay and the Green River.

Spatial and temporal variations of variable values in the estuary and Puget Sound are observed by continuous monitoring at several locations and by data collected during field investigations. In addition to the usual graphical and statistical analysis and interpretation of data, a numerical (digital) model of a salt-wedge estuary has been developed and applied to the Duwamish estuary. The model has been calibrated and verified with observed data to compute distributions of salinity, temperature, chlorophyll a (phytoplankton) concentration, BOD, and dissolved-oxygen concentration in the estuary. Also dissolved-oxygen concentrations in the Duwamish estuary when the Renton Treatment Plant discharges a proposed future maximum of 223 cubic feet per second (6.31 cubic meters per second) have been estimated.

#### Author's Abstract

Lee, F.A. Ongoing research. Circulation and Mixing in Duwamish Estuary. For, University of Washington, Department of Oceanography, in: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

Based on U.S.G.S. data on current and salinity of Duwamish River. Both circulation and mixing mechanisms will be investigated. A numerical model will be constructed to simulate the dynamics of the estuary.

#### Author's Abstract

Lenarz, W.H. 1969. Analysis and evaluation of data obtained from automatic water quality monitoring stations on the Duwamish Estuary, Seattle. Ph.D. Thesis, University of Washington, College of Fisheries, Seattle. 189 pp.



A completely computerized system for screening, summarizing and analyzing a continuous stream of multivariate environmental data collected by a network of remote electronic monitoring stations is described. This system was tried on data collected by the Municipality of Metropolitan Seattle in the Green-Duwamish River system and in the Duwamish-Elliott Bay complex where hourly readings of water temperature, conductivity, dissolved-oxygen, pH, and solar radiation are recorded. Included is a series of computer programs to carry out screening, summarization and statistical analyses involving both multiple regression and spectral analysis. A considerable amount of information on the physical parameters is synthesized to describe their interactions with the biological components.

Matsuda, R.I. Ongoing research. Seasonal fluctuations and species composition of fishes in the Duwamish Waterway. For, Municipality of Metropolitan Seattle, in: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

A one year study was carried out to document seasonal population fluctuations and species composition of the fishes in the Duwamish Waterway. Data collected from this study will be compared with data collected from a previous study to determine if changes in the seasonal fluctuations and species composition have occurred and to determine the possible reasons for these changes.

Data was also collected on fish diseases (i.e., tumors and fin rot).

#### Author's Abstract

Matsuda, R.I., G.W. Isaac and R.D. Dalseg. 1968. Fishes of the Green-Duwamish River. Municipality of Metropolitan Seattle, Water Quality Series No. 4, 38 pp.

Since no historical information could be found on the fishes of the Green-Duwamish River, Metro's fish studies were initially designed to document the various fishes inhabiting the Green-Duwamish River and Duwamish waterway. Thirty different fish species were documented during the three-year (1964-66) study.

The seasonal and yearly population fluctuations and trends of four species were studied to assess the effects of effluent discharged from the Renton Treatment Plant on these populations. Two of the four species, the shiner perch and staghorn sculpin, increased in population. The starry flounder population remained constant and the chinook salmon fry and fingerling population declined at one station and was variable at the other.

#### Author's Abstract

Miller, B.S., R.C. Wingert and S.F. Borton. 1974. Ecological Survey of Demersal Fishes in the Duwamish River and at West Point, (Jan-Dec 1974). Municipality of Metropolitan Seattle, Contract No. 9684. 35 pp.

During 1974, the Fisheries Research Institute at the University of Washington conducted sampling of demersal fishes in the Duwamish River and at West Point. The objectives of both sampling programs were to: (1) obtain data on species composition, distribution, abundance, and community structure; and (2) obtain information on disease incidence and parasite infestation. Disease studies have emphasized fin rot, tumors, and nematode parasites. This progress report describes sampling procedures and preliminary results on these investigations for the year 1974.

#### Author's Introduction

Murray, H.R. 1972. Study on Effect of Dredging on Water Quality and Sediment Transport in the Duwamish Estuary. U.S. Army Corps of Engineers; Consult. Rep. for the Seattle District Headquarters by Stevens, Thompson and Runyon, Contract No. DACW67-72-C-0116.

The hydrology, sediments, and water quality of the Duwamish estuary were studied in terms of the impact that dredging and disposal operations could be expected to have on these parameters. Besides a discussion of the probable direct impact of navigation projects in the estuary, alternatives for dredging and disposal operations are given, and recommendations were presented for improved methods of dredging and disposal. Short term effects of engineering activities in the estuary would be a significant increase in turbidity and a much smaller effect on dissolved oxygen and release of nutrients and metals. Long term effects would include changes in the hydraulics, sediment transport, and water quality of the estuary.

Prych, E.A., W.L. Haushild and J.D. Stoner. 1975. Numerical Model of the Salt-Wedge Reach of the Duwamish River Estuary, King County, Washington. U.S. Geological Survey Open-file Report 75-13.

A numerical model of a salt-wedge estuary developed by Fischer has been expanded and used to calculate the distributions of salinity, temperature, chlorophyll a concentrations, biochemical oxygen demand, and dissolved-oxygen concentrations in the Duwamish River estuary, King County, Wash. With this model, which was calibrated and verified with observed data, computer temperatures usually agreed within 2° Celcius of observed temperatures. During a phytoplankton bloom in the summer of 1968 the computed chlorophyll a concentrations increased and decreased with the observed concentrations; however, during two blooms in 1967 the computed high concentrations persisted farther

downstream and lasted a few days longer than the observed concentrations. The computed and observed dissolved-oxygen concentrations usually agreed within 2 milligrams per litre, except during phytoplankton blooms. During the blooms, the differences were often larger, especially when the computed chlorophyll a concentrations were larger than the observed concentrations.

The model was used to predict the dissolved-oxygen concentrations in the Duwamish River estuary when the Renton Treatment Plant sewage-effluent discharge is increased to its proposed maximum of 223 cubic feet per second (6.31 cubic meters per second). The computed monthly average dissolved-oxygen concentrations in the estuary decreased by a maximum of 2 milligrams per litre when compared with computations for the summer of 1971, when the effluent discharge averaged 37 cubic feet per second (1.05 cubic meters per second). The increase in effluent discharge is not expected to cause large changes in phytoplankton concentrations in the estuary.

#### Author's Abstract

Rattray, M., Jr. and E. Mitsuda. 1974. Theoretical Analysis of Conditions in a Salt Wedge. *Estuarine and Coastal Marine Science*. 2(4): 375-394.

Theoretical results are obtained for salt-wedge estuaries which give the velocity profile, stress distribution, shape and length of the wedge for steady-state flow conditions. It is assumed that the cross-section is rectangular. Cases are presented for both constant depth and uniformly sloping bottom. The dynamics resemble those found in open channel flow with the addition of a laminar boundary layer at the interface between the wedge and the upper layer.

The theory gives reasonable predictions for the length and shape of salt wedges observed in flumes and in the Mississippi and Duwamish Rivers.

#### Author's Abstract

Santos, J.F. and J.D. Stoner. 1972. Physical, Chemical, and Biological Aspects of the Duwamish River Estuary King County, Washington 1963-67. U.S. Geological Survey Water-Supply Paper. 1873-C. 74 pp.

This report describes the significant results to 1967 of a comprehensive study that began in 1963 to evaluate what changes take place in an estuary as the loads of raw and partially treated industrial and municipal wastes are replaced by effluent from a secondary treatment plant. The study area is the Duwamish River estuary.

Four water-quality stations automatically monitor DO (dissolved oxygen), water temperature, pH, and specific conductance; at one station solar radiation also is measured. DO concentration in the surface layer decreases almost linearly in a downstream direction. Minimum DO concentration in the surface layer is usually greater than 4 mg/l (milligrams per liter). The smallest DO values are consistently recorded in the bottom layer at the station 7.7 kilometers above the mouth; monthly means of less than 3 mg/l of DO have occurred at this point. Manual sampling shows that the DO sag in the bottom layer oscillates between 7.7 and 10.4 kilometers above the mouth of the estuary. Multiple-regression analysis shows that the surface DO content can be estimated from the fresh-water inflow and water temperature. Tidal exchange and fresh-water inflow indirectly control the bottom DO content. Average nitrate concentration in fresh water at station 16.2 has increased progressively since 1964, by amounts greater than those which can be attributed to the Renton Treatment Plant, 4.3 kilometers upstream from station 16.2

The BOD (biochemical oxygen demand) in both surface and bottom layers is generally less than 4 mg/l of oxygen, but values greater than 6 mg/l have been measured during a period of phytoplankton bloom. Phytoplankton blooms can occur during periods of minimum tidal exchange and fresh-water inflows of less than 300 cfs if solar radiation and water temperature are optimum. Nutrients (nitrogen and phosphorus compounds) do not control the occurrence of a bloom, because sufficient

quantities of these nutrients are always present. Nutrients in the treated effluent may increase the biomass of the bloom. Trace-element studies have not defined any role that these elements may play in algal growth.

The inflowing fresh water contains principally calcium and bicarbonate and has a dissolved-solids content ranging from 33 to 71 mg/l. During the study period, concentrations of suspended sediment ranged from 20 to 1,000 mg/l, and the maximum sediment load was 31,000 tons per day. Because bottom deposits contain large amounts of coal from upstream sources, it was not possible to quantitatively determine other organic material by carbon analysis.

#### Shortened Author's Abstract

Schell, W.R. and E.E. Collias. Ongoing research. Trace Contaminants from Dredge Spoils in Elliott Bay. For, Municipality of Metropolitan Seattle, in: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

The Duwamish Waterway is presently being dredged; the accumulated dredge material is being dumped off Four Mile Rock in Elliott Bay. These activities pose the threat of possible interference with METRO interim studies now being conducted in the area of the dump site. The present study was initiated to measure the increase over ambient concentrations of trace constituents in Elliott Bay and nearby waters due to the disposal operations. Transport of trace constituents by the current and tidal circulation and the distribution of these constituents within the biological system of the estuary are also under study.

#### Shortened Author's Abstract

Stoner, J.D. 1972. Determination of Mass Balance and Entrainment in the Stratified Duwamish River estuary, King County, Washington. U.S. Geological Survey Water-Supply Paper. 1873-F. 17 pp.

During a study of the effects of waste-water input on the stratified Duwamish River estuary, intensive water-velocity and salinity measurements were made in both the lower salt wedge and the upper fresher water layer for tidal-cycle periods. The net movement of water and salt mass past a cross section during a tidal cycle was determined from integration of the measured rates of movement of water and salt past the section. The net volume of water that moved downstream past the section during the cycle agreed with the volume of fresh-water inflow at the head of the estuary within (1) 3.8 and 7.2 percent, respectively, for two studies made during periods of maximum and minimum tidal-prism thickness and identical inflow rates of 312 cfs (cubic feet per second), and (2) 15 percent for one study made during

a period of average tidal-prism thickness and an inflow rate of 1,280 cfs. For the three studies, the difference between salt mass transported upstream and downstream during the cycles ranged from 0.8 to 1.9 percent of the respective mean salt-mass transport. Water was entrained from the salt-water wedge into the overlying layer of mixed fresh and salt water at tidal-cycle-average rates of 30 and 69 cfs per million square feet of interface for the inflow rates of 312 cfs, and 99 cfs per million square feet of interface for an inflow rate of 1,280 cfs. At a constant inflow rate, the rate of entrainment of salt-wedge water in the Duwamish River estuary more than doubled for a doubling of tidal-prism thickness. It also doubled for a quadrupling of inflow rate at about constant tidal-prism thickness.

Author's Abstract

Stoner, J.D. 1967. Prediction of Salt-Water Intrusion in the Duwamish River Estuary, King County, Washington. Geological Survey Research, U.S. Geological Survey Prof. Paper. 575-D. pp. 253-255.

Accurate predictions of salt-water intrusion 7.8 miles upstream from the mouth of the Duwamish River can be made for the 3-foot surface layer, using the relationship between tide height and fresh-water discharge. Intrusion occurs at the site regardless of the high-tide height, when discharge is less than 625 cfs, whereas a discharge of more than 1,000 cfs is sufficient to prevent intrusion at any tide stage. Between 625 and 1,000 cfs, intrusion is dependent upon both discharge and high-tide height.

Author's Abstract

Tilley, L.J. and W.A. Dawson. 1971. Plant nutrients and the estuary mechanism in the Duwamish River estuary. U.S. Geological Survey Prof. Paper 750-C. pp. 185-191.

The Duwamish River estuary traps plant nutrients in the water of its salt wedge. Analyses of input and output of nutrient concentrations in the estuary show a nearly two-fold increase in concentrations of nutrients in the salt wedge. The increase consists of nutrients transferred from the outflowing river water in amounts which barely affect river-water concentrations.

Author's Abstract

Welch, E.B. 1969. Factors Initiating Phytoplankton Blooms and Resulting Effects on Dissolved Oxygen in Duwamish River Estuary, Seattle, Washington. U.S. Geological Survey Water-Supply Paper 1873-A. 62 pp.

Phytoplankton productivity, standing stock, and related environmental factors were studied during 1964-66 in the Duwamish River estuary, at Seattle, Wash., to ascertain the factors that affect phytoplankton growth in the estuary; a knowledge of these factors in turn permits the detection and evaluation of the influence that effluent nutrients have on phytoplankton production. The factors that control the concentration of dissolved oxygen were also evaluated because of the importance of dissolved oxygen to the salmonid populations that migrate through the estuary.

Phytoplankton blooms, primarily of diatoms, occurred in the lower estuary during August 1965 and 1966. No bloom occurred during 1964, but the presence of oxygen-supersaturated surface water in August 1963 indicates that a bloom did occur then.

Nutrients probably were not the primary factor controlling the timing of phytoplankton blooms. Ammonia and phosphate concentrations increased significantly downstream from the Municipality of Metropolitan Seattle's Renton Treatment Plant outfall after the plant began operation in June 1965, and concentrations of nitrogen and phosphorus were relatively high before operation of the Renton Treatment Plant and during nonbloom periods. The consistent coincidence of blooms with minimum fresh-water discharge and tidal exchange during August throughout the study period indicates that bloom timing probably was controlled mostly by hydrographic factors that determine retention time and stability of the surface-water layer. This control was demonstrated in part by a highly significant correlation of gross productivity with retention time (as indicated by fresh-water discharge) and vertical stability (as indicated by the difference between mean surface and mean bottom temperatures). The failure of a bloom to develop in 1964 is related to a minimum fresh-water discharge that was much greater than normal during that summer. Hydrographic factors are apparently important because, as shown by studies of other estuarine environments by other workers, phytoplankton production increases when the zone of vertical turbulent mixing is not markedly deeper than the compensation depth.

Phytoplankton cells produced in the surface waters sink, thereby contributing oxidizable organic matter to the bottom saline-water wedge. The maximum BOD (biochemical oxygen demand) in this bottom wedge occurs in the same section of the estuary and at the same time as the maximum phytoplankton biomass (as indicated by chlorophyll a) and minimum DO (dissolved oxygen). Other sources of BOD occur in the estuary, and conditions of minimum discharge and tidal exchange assist in reducing DO. Nonetheless, the highly significant correlation of chlorophyll a with BOD throughout the summer indicates that respiration and decomposition of phytoplankton cells is clearly an important contributor of BOD.

Increases in the biomass and resultant BOD of blooms because of increased effluent nutrients presumably would further decrease the concentration of DO. This possible effect of effluent nutrients was evaluated by laboratory bioassays and by a comparison of mean annual biomasses in the estuary. A green algal population in vitro did increase in response to added effluent nutrients; however, the available field data suggest that a 46-percent increase in effluent discharge between 1965 and 1966 did not increase the estuary's phytoplankton biomass significantly.

#### Author's Abstract

Welch, E.B. 1968. Phytoplankton and related water-quality conditions in an enriched estuary. Water Pollution Control Federation, Journal, 40(10): 1711-1727.

The purpose of this study is to evaluate the influence of nutrient additives from the effluent of the recently completed Renton Treatment Plant on phytoplankton standing stock, productivity and species composition in the Duwamish estuary at Seattle, Washington. This evaluation is done in relation to physical and chemical factors to evaluate possible changes in water quality as a result of phytoplankton blooms that might occur as the volume of the plant effluent increases.

Williams, J.R. 1967. Movement and dispersion of a fluorescent dye in the Duwamish River estuary, Washington. U.S. Geological Survey Prof. Paper 575-B. pp. 245-249.

Rhodamine B was introduced 13.1 miles above the Duwamish River mouth on a falling tide, with a discharge of about 700 cfs, and dye concentrations were measured continuously for 67 hours at sites 5.4 and 8.3 miles downstream from the point of release. Times of travel to the 2 sites were 5 hours 2 minutes and 18 hours and 40 minutes, respectively. Dye concentrations and travel times for all but the first peak at the upstream site were affected by tide. The dispersion coefficient at the downstream site (200 and 400 sq ft/sec) was considerably larger than that at the upstream site (about 100 sq ft/sec) because of the tidal action.

#### Author's Abstract



BENTHIC AND PELAGIC ASSEMBLAGES IN PUGET SOUND AND THE NORTHEASTERN  
PACIFIC OCEAN: WITH GENERAL REFERENCES TO PHYSICAL AND CHEMICAL  
PROPERTIES OF PUGET SOUND

Alverson, D.L., A.T. Pruter, and L.L. Ronholt. 1964. A study of demersal fishes and fisheries of the northeastern Pacific Ocean. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Inst. Fish., 190 pp.

To evaluate the effects of fisheries on groundfish populations requires that all available facts be marshalled, including information on the fisheries themselves and on the distribution and relative abundance of the various species in time and space. The purpose of this report, therefore, is to (1) review the development and magnitude of demersal fisheries in the northeastern Pacific Ocean, (2) describe the gear and fishing techniques used to harvest the resources, (3) summarize results of exploratory fishing surveys to provide information on the distribution, relative abundance, and sizes of demersal fishes inhabiting the continental shelf and continental slope off North America from Oregon to the Bering Sea, and (4) consider the magnitude and current use of demersal fish stocks.

Collias, E.E., N. McGary and C.A. Barnes. 1974. Atlas of physical and chemical properties of Puget Sound and its approaches. Washington Sea Grant Publication WSG 74-1, University of Washington, Seattle, 235 pp.

This is a graphic presentation of the physical and chemical oceanographic data from Puget Sound and its approaches which provides a convenient and usable reference for defining the major features of water properties in Puget Sound. Water properties along 8 longitudinal profiles are presented for varying time intervals from 1952 through 1966. The major features of the distribution of properties can be followed as they change in space and time. Values for different years at corresponding seasons can be compared to give an insight into the year-to-year variations. Measurements were made along the major axes of the various channels and represent locally the background saline waters that feed the peripheral areas.

DeLacy, A.C., B.S. Miller and S.F. Borton. 1972. Checklist of Puget Sound Fishes. Washington Sea Grant Program, Division of Marine Resources, University of Washington, 43 pp.

The accompanying list of fishes constitutes a compilation of data on Puget Sound fish species distribution up to 1971. It is compiled from the literature; from unpublished catalogued entries in the University of Washington collection of fishes; and from unpublished log records from the University of Washington College of Fisheries, University of Washington Department of Oceanography, University of Washington

Friday Harbor Laboratories, Washington State Department of Fisheries, National Marine Fisheries Service, Municipality of Metropolitan Seattle, and other less extensive sources. We have tried to avoid any duplication of reports and have made the general nature of this list conservative, since we have attempted to avoid any reports of questionable validity. A total of 211 species of fish have been recorded in this checklist.

#### Shortened Author's Introduction

DiDonato, G. 1971. Groundfish Investigations Progress Report - 1970. Washington Department of Fisheries, Marine Fisheries Investigations.

This report contains a general review of the 1970 Washington trawl fishery with records of groundfish tag release and recovery records. Reviews of present studies and of interstate and international meetings as well as any regulation changes are also included. Miscellaneous other programs such as Puget Sound English sole stock delineation studies, Central Puget Sound trawl vessel sampling studies and Everett Bay dumping problem are discussed. Mention of the reports finished and/or published during 1970 is also made.

DiDonato, G. 1971. Groundfish Investigations Progress Report - 1969. Washington Department of Fisheries, Marine Fisheries Investigations.

This report contains a general review of the 1969 Washington trawl fishery along with tagging studies. Of main concern were the changes in groundfish regulations, the proposals and their justifications based on areas of Puget Sound being fished and to what extent. Other activities such as meeting reviews and mention of other programs, as well as those reports completed and/or published during 1969 were discussed.

Federal Water Pollution Control Administrator. Conference on the matter of pollution of the navigable waters of Puget Sound, the Strait of Juan de Fuca and their tributaries and estuaries (Washington). U.S. Department of the Interior.

This conference deals with the matter of pollution of navigable water of the Puget Sound and surrounding areas. The purpose of the conference is to bring together authoritative and interested parties to review the existing situation, progress and lay a basis for further research.

Friebertshauser, M. and A.C. Duxbury. 1972. A water budget study of Puget Sound and its subregions. *Limnol. Oceanogr.*, 17: 237-247.

A water budget study for Puget Sound and its principal subregions, based on the freshwater, seawater, and total water budgets, determines the mean fluxes of water into and out of these regions, the freshwater content, and the change in freshwater content by month and by year.

Data used to calculate the budgets include monthly mean values of precipitation, evaporation, runoff, changes in sea level, mean salt content, and the salinities of inflowing and outflowing waters for each subregion. The fluxes of water calculated in the budget analysis yield an approximation of flushing efficiency and replacement time for Puget Sound and its subregions. The monthly freshwater content, along with the fluxes of water and their salt load, indicates that river runoff does not by itself control the freshwater content of a particular subregion; considerable freshwater is added by the inflow of water from an adjacent embayment.

Grinols, R.B. 1965. Checklist of the offshore marine fishes occurring in the NE Pacific Ocean, principally off the coasts of British Columbia, Washington, and Oregon. M.S. Thesis, University of Washington, College of Fisheries, Seattle, 217 pp.

The origin, dispersal, and abundance of northeastern Pacific deep-water marine benthic fishes are examined with a brief discussion of deep-sea endemism. Oceanic provinces are discussed and delimited.

About 200 pelagic, bathypelagic and benthic species, belonging to 127 genera and 59 families have been reported. Based on recent, new information, 24 species of deep-water marine fishes have been added to the subarctic faunal area.

#### Author's Abstract

Harman, R.A., J.C. Serwold and marine technicians. 1974. Baseline study of sediment provinces and biotypes of Elliott Bay and vicinity, Washington. Shoreline Community College, Marine Technical Report No. 2.

The suspended load from the Duwamish River is deposited on the eastern portion of Elliott Bay while its bedload is deposited on the western side. Distribution of diatoms, foraminifers, pelecypods, gastropods and specimens from polychaete worm families are influenced by this suspended load distribution. Water stratification and advection are more important in accounting for the distribution of river born particles than vertical sinking since most debris does not accumulate below the 50 fathom contour despite close proximity to the river mouth. The distribution of Foraminifera and diatoms as compared to the macrofauna also appear to respond to water stratification in that their distribution is controlled more by water depth. Although the macrofauna are influenced by river sedimentation, their distribution over greater depth ranges also suggest the importance of shelf displacement or vertical transport of food by plankton or nekton. The western portion of Elliott Bay and the shelves outside of Elliott Bay have more diverse faunas. Shelf displacement appears to affect the numbers of benthic organisms in the deep areas of Puget Sound. The former dumpsite off Fourmile Rock has reduced the macrofauna density but has not noticeably altered the adjacent macrofauna sites where dumped debris has dispersed. Hardpan clays should not be dumped in marine environments as both micro and macrofaunal components are drastically reduced.

#### Author's Abstract

Harman, R.A., R.E. Sylwester and marine technicians. 1974. Microbiogenic sediments and their use in evaluating estuaries in central Puget Sound, Washington. Shoreline Community College, Marine Technical Report No. 1.

In Central Puget Sound, centric or disc shaped diatoms such as Coscinodiscus species dominated the deeper portions of estuaries. Angular shaped diatoms such as Biddulphia and Ischnia species are more frequently found in higher salinity waters or current swept rocky and gravelly areas. Rod and chain diatoms, such as Milosiranae, were common in low salinity waters, especially on mud flats and eastern portions of Puget Sound. Pennate diatoms characterize river beds or inner portions of tidal flats. Differences between Foraminifera faunas reflected the influence of substrate and salinity differences. In current swept passage a greater diversity of species in the micro-fauna existed. Mudflats contain predominantly Trochamina inflata and Miliammina fusca while sandy tidal flats were dominated by Trochamina pacifica. Estuaries with lower salinities were more frequented by Elphidium selseyense while Elphidiella hanna were typically more seaward. In the main Puget Sound basin eggerella advena and Legenammia atlantica were dominant but appeared to be excluded from the more distant estuaries of Sinclair Inlet, Dyes Inlet and Liberty Bay. Wood fragments appeared to be controlled by advection and water stratification. Since their concentrations were low in deeper waters despite their near proximity. Off the old and new sewer outfall at Metro tideflat species, Trochamina inflata, was found in deep water (30 fathoms) suggesting possible influence of either the old or new sewer outfall. Both polluted and glacial sediment should have lower foraminiferal concentrations than normal modern day sediments. Elphidium selseyense, Pennate diatoms and Milosiranae should dominate glacial sediments while arenaceous foraminiferal faunas will be found dominating polluted sediment in Central Puget Sound.

#### Author's Abstract

Kozloff, E.N. 1973. Seashore life of Puget Sound, Strait of Georgia, and the San Juan Archipelago. University of Washington Press, Seattle.

This book is a reasonably comprehensive, accurate and well illustrated guide to the seashore life of Puget Sound and adjacent waters. Discussions are organized into three habitat-oriented chapters, covering floating docks and pilings, rocky shores, and sandy and muddy habitats.

Lie U. 1974. Distribution and structure of benthic assemblages in Puget Sound, Washington, U.S.A. Marine Biology, 26: 203-223.

Benthic infauna was collected with a  $0.2 \text{ m}^2$  van Veen grab at 48 stations in Puget Sound, Washington, USA during February-March 1969. All the crustaceans, lamellibranchs, and echinoderms were identified and counted. Particle size distributions and nitrogen contents of the sediments, depths, and temperature and salinity of the bottom water

were determined at all stations. The first three factors of a factor analysis applied to between-stations measures of affinity, explained 41.26% of the total variance. The first factor had representative stations on shallow-water mud bottoms, the second factor on bottoms dominated by coarse sediments, and the third factor had representative stations on deep-water mud bottoms. The multiple correlation coefficients for each of the three factors with depth and mean particle size of the sediments were 0.752, 0.897, and 0.706, respectively. The factor analysis did not result in clusters of stations that could be interpreted as discrete benthic communities. The number of species per  $0.6 \text{ m}^2$  ranged from 8 to 55 species, with a mean of 26.4 species. The frequency distribution of specimens among the species was in good agreement with a log-normal distribution. The number of specimens per  $0.6 \text{ m}^2$  ranged from 57 to 1733 specimens, with a mean of 584.0 specimens. The species diversity ranged from 0.34 bits/individual to 4.35 bits/individual, and there was a weak trend of increasing diversity towards coarser sediments. The first three factors applied to the matrix of between-species correlation coefficients explained 43.72% of the total variance. With each factor there was one group of species with high positive loadings and one group with high negative loadings. Each group of species could be identified with particular environments. The standing crop, measured as ash-free dry weight, ranged from 0.490 to 54.093  $\text{g/m}^2$ , with a mean of 13.752  $\text{g/m}^2$ . Only about 24% of the variability in standing crop could be attributed to variability in sediment types, nitrogen content in the sediments, salinity of the bottom water, and depth.

#### Author's Abstract

- Lie U. 1969. Standing crop of benthic infauna in Puget Sound and off the coast of Washington. Fisheries Research Board of Canada, Journal, 26(1): 55-62.

During the period May 28 to August 1, 1967, benthic infauna was collected at 37 stations in Puget Sound and off the coast of Washington. When large but rare species were excluded from the samples, the variability in standing crop (ash-free dry weight) among replicate samples was less than among means from different stations. The mean standing crop for the offshore stations was 1.92  $\text{g/m}^2$ , which is comparable with the standing crop on the shelf in the Gulf of Alaska, but less than half the mean standing crop for the Puget Sound stations; the difference may be explained in part by differences, previously reported, in primary productivity of the water masses. For the offshore stations there was a weak trend of increasing standing crop with depth. The standing crop at the shallow-water offshore stations, in substrates characterized as fine sand, was dominated by crustaceans and small lamellibranchs, whereas the deeper stations, in sediments with high percentages of silt and clay, polychaetes and echinoderms were the most important contributors.

#### Author's Abstract

Lie, U. and R.A. Evans. 1973. Long-term variability in the structure of subtidal benthic communities in Puget Sound, Washington, U.S.A. *Marine Biology*, 21: 122-126.

Data on benthic infauna from 4 permanent stations in Puget Sound off Seattle, U.S.A., collected during 1963-1964, 1967, and 1969, revealed considerable stability in numbers of species and specimens and in diversity within stations among sampling dates. The species composition of the faunal assemblages also remained rather constant during the period of investigation, but the relative dominance among the numerically important species varied somewhat. Biomass data did not differ significantly in 1964 and 1969, but the 1967 data were considerably lower at all stations.

#### Author's Abstract

Lie, U. and J.C. Kelley. 1970. Benthic infauna communities off the coast of Washington and in Puget Sound: identification and distribution of communities. *Fisheries Research Board of Canada, Journal*, 27: 621.

Benthic infauna was collected at 37 stations in Puget Sound in Juan de Fuca Strait, and off the northwestern coast of Washington during the summer of 1967, and at 18 additional stations off the southwestern coast of Washington during the summer of 1968. The crustaceans, lamellibranchs, and echinoderms were identified and counted, and the data were subjected to an analysis of affinity among stations, to Fager's recurrent group analysis, and to factor analysis for identification of the benthic communities and the groupings of benthic species in the investigated area.

Trellis-diagrams of indices of affinity among the stations, based on the presence or absence of species, indicated four rather distinct groups of stations with specific geographic distributions or relations to certain sediment types. Fager's recurrent group analysis for the 36 most frequently occurring species resulted in eight groups and five species that were strongly associated with one or more of the recurrent groups. Most tests of inter-specific relations among the species within the groups were not significant, and it was concluded that the analysis was only partly useful for delimiting species groups with ecological significance. The Q-mode of the factor analysis resulted in three groups of stations distributed in bands parallel to the coast, and each group of stations (community) could be recognized by its distinct sediment types or depth distribution. The R-mode of the factor analysis gave six groups of species with specific preferences of depths, sediment types, or geographic distribution. The results of the various techniques were compared, and their application in benthic synecology was discussed.

#### Author's Abstract

Lie, U. and E.S. Kisker. 1970. Species composition and structure of benthic infauna communities off the coast of Washington. Fisheries Research Board of Canada, Journal, 27: 2273-2285.

The deepwater mud-bottom community identified previously as one of three benthic infauna communities off the coast of Washington was found at mean depths of 154.5 m in sediments with a mean mud percentage of 50.09%. The most abundant species were the polychaetes Prionospio malmgreni, Sternaspis fossor, and Ninoe gemmea, the lamellibranchs Axinopsida serricata, Adontorhina cyclia, and Macoma carlottensis, and the amphipod Heterophoxus oculatus. The mean standing crop (ash-free dry weight) was 3.058 g/m<sup>2</sup>, with the echinoderms Brisaster latifrons, Ophiura lutkeni, and Amphioplus sp. and the polychaete Sternaspis fossor as the major contributors to the standing crop.

The intermediate depth sand-bottom community was found at stations with a mean depth of 95.8 m in sediments with a mean sand percentage of 67.81%. The most abundant species were the polychaetes Magelona sp., Sternaspis fossor, Nephtys sp., and Haploscoloplos elongatus, the lamellibranchs Yoldia ensifera and Axinopsida serricata, and the amphipod Paraphoxus variatus. The mean standing crop was 2.533 g/m<sup>2</sup>, with the species listed above and the lamellibranch Macoma elimata as the major contributors to the standing crop.

The shallow water sand-bottom community was found at stations with a mean depth of 36.0 m in sediments with a mean sand percentage of 96.33%. The most abundant species were the cumacean Diastylopsis dawsoni, the amphipods Ampelisca macrocephala and Paraphoxus obtusidens, the lamellibranchs Tellina salmonea and Macoma expansa, and the polychaete Owenia fusiformis. The mean standing crop was 1.398 g/m<sup>2</sup>, with the species listed above and the polychaetes Nephtys sp<sup>2</sup> and Chaetozone setosa and the lamellibranch Siliqua patula as the major contributors to the standing crop.

There was a distinctly lower species diversity in the shallow water sand-bottom community than in the two communities in deeper waters.

#### Author's Abstract

Nichols, F.H. Ongoing research. Long-term stability of the benthic invertebrate community of Puget Sound Basin. By: U.S. Geological Survey, In: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

With routine field sampling from shipboard at three stations (47°44.2'N, 122°32.2'W; 47°41.9'N, 112°27.2'W; 47°33.7'N, 122°26.5'W) twice annually, long-term variations in the dynamics of the benthic invertebrate species populations in the Puget Sound Basin are being followed. That is, the annual variability associated with recruitment and growth in the dominant species populations of the Puget Sound

seabed is being assessed and it is being determined whether or not there is any significant change in the structure of the bottom community over long periods. Results obtained thus far are described in the abstracts of papers recently presented at two meetings.

#### Author's Abstract

Pattie, B.H. Ongoing research. Estuarine Monitoring Project. For, Environmental Studies in Puget Sound and Northwest Estuarine Waters.

The National Estuarine Monitoring Program is intended to determine the presence and magnitude of certain pollutants in various estuarine waters throughout the United States. The Washington State Department of Fisheries was first contracted for the collection and processing of samples from various estuaries in the State of Washington during the fall of 1972. Two species of fish: Parophrys vetulus; and Staghorn sculpin, Leptocottus armatus are collected from six sites in Washington State, (1) Bellingham Bay, (2) Duwamish River, (3) Nisqually Estuary, (4) Seabeck Bay, (5) Grays Harbor, and (6) Willapa Bay. The fish samples are processed in the Seattle office of the Washington State Department of Fisheries, and mailed to the Environmental Protection Agency Pesticides Monitoring Laboratory, Mississippi Test Facility, Bldg. 2204, Bay Street, Louis, Mississippi. They are analyzed for contamination by pesticides and heavy metals.

#### Author's Abstract

Winter, D.F. 1973. A similarity solution for steady-state gravitational circulation in fjords. Estuarine Coastal Marine Science, 1(4): 387-400.

Stratified estuaries with relatively deep, laterally constricted basins are commonly referred to as fjords. The dominant circulation mode of fjords which receive ample fresh water runoff is gravitational convection, which takes place primarily near the surface in a brackish phase with one or two current reversals. An analysis is made of steady-state gravitational circulation in the near-surface zone. Approximate analytic expressions are obtained for the velocity components and the density distribution in a fiord segment where conditions for a similarity analysis are satisfied.

The method is illustrated by applications to Hood Canal and the central basin of Puget Sound, Washington (U.S.A.), and to Knight Inlet on the mainland coast of British Columbia, Canada. Comparisons of measured and computed salinity and velocity profiles indicate that the circulation patterns are reasonably well represented by the approximate solutions. The flow description given here may be of some use in studies of pollutant dispersal and biological production in fjords.

#### Author's Abstract



POLYCHLORINATED BIPHENYLS: THEIR OCCURRENCE IN THE ENVIRONMENT AND  
THEIR EFFECT ON SOME MARINE ORGANISMS

Claeys, R.R., R.S. Caldwell, N.H. Cutshall and R. Houlton. 1975. Chlorinated pesticides and polychlorinated biphenyls in marine species, Oregon/Washington coast, 1972. Pesticide Monitoring Journal, 9(1): 2-10.

Concentrations of chlorinated pesticides and polychlorinated biphenyls (PCB's) were determined in three offshore marine species from the Oregon/Washington coast: pink shrimp, euphausiids, and flatfish; five species of bivalve mollusks from five estuaries along the Oregon coast; several fish species from the Coos Bay and Columbia River estuaries; and a summer run of steelhead from the Rogue River.

The compounds p,p'-DDE and PCB's were detected most frequently. Euphausiids and pink shrimp contained approximately 2 ppb (ug/kg) wet-weight DDE and 8 and 25 ppb PCB's, respectively. Offshore flatfish contained an average of 9 ppb DDE and 29 ppb PCB's. DDE residues in estuarine mollusks approximated 0.5 ppb. PCB levels were not detectable (<3 ppb) except in collections from the mouth of the Columbia River where levels averaged 400 ppb PCB's and 17 ppb DDT. Selected Columbia River fish species contained 38 ppb DDE and 480 ppb PCB's; summer-run steelhead in the Rogue River contained 97 ppb DDE and 125 ppb PCB's.

PCB chromatograms of most euphausiids closely resembled those of Aroclor 1254. Chromatograms of shrimp and flatfish indicated selective metabolism of two compounds in the Aroclor 1254 formulation. Biphenyls of higher chlorine content were also detected in the shrimp and flatfish.

Author's Abstract

Crump-Wiesner, H.J., H.R. Feltz and M.L. Yates. 1974. A study of the distribution of polychlorinated biphenyls in the aquatic environment. Pesticide Monitoring Journal, 8(3): 157-161.

Data gathered from monitoring activities and project studies indicate the ubiquitous occurrence and distribution of polychlorinated biphenyls (PCB's) in the aquatic environment. By 1972 residues had been detected in samples from 19 States representing nearly every region of the country. These findings permit a preliminary assessment of PCB contamination across the Nation: concentrations ranged from 0.1 to 4.0 ug/liter in unfiltered water samples and from 5.0 to 3,200 ug/kg in bottom sediments. PCB residues were also found in fish and aquatic plants. Samples were prepared by the same techniques used for general chlorinated insecticide detection, with special attention to cleanup and separation of PCB's from other compounds. Basic identification and quantification were made by dual-column electron-capture/gas-liquid chromatography and confirmed by gas-liquid chromatography/mass spectrometry whenever possible. In sediment samples from a south Florida drainage ditch,

polychlorinated naphthalenes (PCN's) were observed. This is possibly the first evidence of PCN's in an environmental sample and illustrates the importance of developing analytical capability for the surveillance of other organochlorine compounds that may behave like chlorinated hydrocarbon pesticides.

The sampling program is broadening geographically and gradually increasing to more adequately define the distribution of PCB residues in major drainage basins of the United States.

#### Author's Abstract

Cutkomp, L.K., H.H. Yap, D. Desaiah and R.B. Koch. 1972. The sensitivity of fish ATPases to polychlorinated biphenyls. Environmental Health Perspectives, 1: 165-168.

The ATPase enzyme system in fish is adversely affected by all PCB's studied.  $Mg^{2+}$  ATPase is inhibited to the greatest extent in muscle, but effects in kidney, brain, and liver also occurred. Fifty percent inhibition occurred with less than 1 ppm up to a few ppm. The greatest effects, in vitro, were not on oligomycin-insensitive  $Mg^{2+}$  ATPase, but on oligomycin-sensitive (mitochondrial)  $Mg^{2+}$  ATPase in vivo (chronically-exposed fish). The most effective PCB studied, Aroclor 1242, required a somewhat higher concentration than DDT in comparative in vitro studies.

#### Author's Conclusions

Food and Drug Administration. 1975. Summary report on PCB's in fish. From: EPA meeting held 9/30/75, Seattle, Washington.

The surveillance activities of the Food and Drug Administration relative to PCB residues in fish are directed at FDA's statutory responsibility of assuring that foods are safe for consumption. Since 1969, FDA's pesticide surveillance programs have included the analyses of foods for PCB residues. From 1969 to 1971, FDA field laboratories analyzed about 500 samples of fish and found 317 of these samples to contain PCB residues; levels ranged as high as 35 ppm. Detailed information on these samples is included, with more current data in the attached summaries. In addition, FDA conducted a comprehensive survey of fish in 1973 for a wide variety of chemical contaminants including PCB's. A statistical analysis of the results of this survey as it relates to PCB's is included in this report.

#### Modified Introduction

Goerke, W.E., G. Eder and R.G. Schaefer. 1976. Residues of chlorinated hydrocarbons in marine organisms in relation to size and ecological parameters. I. PCB, DDT, DDE, and DDD in fishes and molluscs from the English Channel. Bulletin of Environmental Contamination and Toxicology, 15(1): 55-65.

In order to provide more data for the characterization of organochlorine residue levels in marine food chains we analysed animals of three areas: English Channel, central North Sea, and eastern North Sea. Animal tissues were investigated for finding possible correlations between residue levels and the body size or ecological parameters.

This paper deals with residues of PCBs, DDT, DDE, and DDD in five species from the English Channel. The organisms were caught either by dredging or bottom trawling on November 26/27, 1971 during the 158th cruise of FFS "Anton Dohrn". The compounds were determined by gas chromatography in two independent working groups, identifications were performed by the GC-MS technique.

#### Modified Author's Introduction

Hansen, D.J. 1974. Aroclor 1254: Effect on composition of developing estuarine animal communities in the laboratory. Mar. Sci., 18: 19-33.

Aroclor 1254, a polychlorinated biphenyl (PCB), affected the composition of communities of estuarine animals that developed from planktonic larvae in salt water that flowed through 10 control aquaria and 10 aquaria contaminated with 0.1, 1 or 10 ug/l of this PCB. Communities that developed in control aquaria and aquaria that received 0.1 g/l of PCB in water for four months were dominated (>75%) by arthropods, primarily the amphipod Corophium volutator. In aquaria receiving 1 and 10 ug/l, the number of arthropods decreased and the number of chordates, primarily the tunicate Mogula manhattensis, increased; over 75% of the animals in 10 ug/l aquaria were tunicates. Numbers of phyla, species, and individuals (particularly amphipods, bryozoans, crabs, and mollusks) were decreased in this PCB, but there was no apparent effect on the abundance of annelids, brachiopods, coelenterates, echinoderms or nemerteans. The Shannon-Weaver index of species diversity was not altered by Aroclor 1254.

#### Author's Abstract

Hansen, D.J., P.R. Parrish, J.I. Lowe, A.J. Wilson, Jr., and P.D. Wilson. 1971. Chronic toxicity, uptake, and retention of Aroclor 1254 in two estuarine fishes. Bulletin of Environmental Contamination and Toxicology, 6(2): 113-119.

Evidence of the global ubiquity of polychlorinated biphenyls (PCB's) continues to mount. High residues of Aroclor 1254 were found in five fishes in an estuary. Chronic toxicity tests to determine effects of low levels of the PCB on finfish (Lagodon rhomboides) and spot (Leiostomus xanthurus), both estuarine fishes were carried out. Concurrently, the uptake and retention of the PCB in six tissues of spot were measured. The results suggest that chronic exposure to Aroclor 1254 increased susceptibility of test pinfish and spot to disease, and also appeared to be toxic to these fish. The PCB is rapidly stored by pinfish and spot, and persists in tissues for approximately three months.

Hansen, D.J., S.C. Schimmel and E. Mathews. 1974. Avoidance of Aroclor 1254 by shrimp and fishes. Bulletin of environmental Contamination and Toxicology, 12(2): 253-256.

The polychlorinated biphenyl (PCB) Aroclor 1254 was found in Escambia River and Bay, which are parts of the estuary near our laboratory. Because it could be an advantage to mobile organisms in the river and bay if they could avoid toxic concentrations of Aroclor 1254, we conducted laboratory studies to determine if pink shrimp (Penaeus duorarum), grass shrimp (Palaemonestes pugis), pinfish (Lagodon rhomboides), sheepshead minnows (Cyprinodon variegatus), and mosquitofish (Gambusia affinis) could avoid water contaminated with 0.001, 0.01, 0.1, 1 or 10 mg/l of the PCB.

#### Modified Author's Introduction

Johansson, N., S. Jensen and M. Olsson. 1970. PCB - indications of effects on fish. In: PCB Conference, September 29, 1970, Wenner-Gren Center, Stockholm, National Swedish Environment Protection Board. pp. 59-68.

Information concerning the effect of PCB residues in fish, or the possible hazard posed by such residues to fish, is presently lacking in the literature. Studies of the effect of the chemical on salmon and salmon reproduction has recently started at the Salmon Research Institute. This paper is concerned with the preliminary results of some of these studies.

Kinter, W.B., L.S. Merkens, R.H. Janicki and A.M. Guarino. 1972. Studies on the mechanism of toxicity of DDT and polychlorinated biphenyls (PCB's). Disruption of osmoregulation in marine fish. Environmental Health Perspectives. 1: 169-173.

DDT was demonstrated to inhibit Na, K<sup>+</sup>ATPase activity in homogenates of intestinal mucosa, and gill fillaments from several marine teleosts. Aroclor 1221 was investigated to determine if it too inhibited enzymatic activity. Overall, the results suggest that lethal levels of Aroclor 1221 and DDT both decrease the ability of killifish to osmoregulate.

McDermott, K.J. and T.C. Heeson. 1975. DDT and PCB in Dover sole around outfalls. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project. pp. 117-121.

During the past year, a new collection of Dover sole from around southern California's five major outfall systems and off Dana Point and Santa Catalina Island were made to determine if there had been any decrease in the levels of total DDT and PCB in this fish over the past 3 years. In conjunction with this survey, the distribution of these chlorinated hydrocarbons in the tissues of Dover sole was investigated as a first step in assessing the physiological significance of the contaminants to the fish.

McDermott, D.J. and M.J. Sherwood. 1975. DDT and PCB in diseased Dover sole. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project. pp. 33-35.

No significant differences between total DDT levels in the muscle tissue of diseased Dover sole collected from the Orange County and from the Palos Verdes regions was found. In contrast, the total DDT concentrations in the unaffected fish from both areas were significantly different. These results give strength to the hypothesis that the Dover sole with fin erosion collected at Orange County came from the Palos Verdes population and that the disease did not originate at Orange County. They also indicate that levels of DDT in tissue may be used as a tag when investigating the migration of fish from or across a region containing a known point source.

Nimmo, D.R. 1974. Accumulation of Aroclor 1254 in grass shrimp (Palaemonestes pugio) in laboratory and field exposures. Bulletin of Environmental Contamination and Toxicology, 11(4): 303-308.

The chronic toxicity and the concentration and loss of Aroclor 1254 from P. pugio with time was examined in the laboratory and in a 3-mo exposure to contaminated sediments in Escambia Bay, Florida. The average whole-body residue in P. pugio after 1 mo was 0.41 mg/kg; after 3 mo, 0.42 mg/kg. Significant mortality did not occur during exposure to contaminated sediments. The 3-mo figure equaled a laboratory exposure of 0.09 ug/l in water for 2 wk. In a 7-d laboratory exposure, 60% of the shrimps died at 9.1 ug/l, but significant mortality did not occur at 0.17 and 0.62 ug/l. In a 16-d exposure, 4.0 and 12.5 ug/l were toxic, but significant mortality did not occur in 1.3 ug/l.

Abstract from Oceanic Abstracts

Nimmo, D.R., P.D. Wilson, R.R. Blackman and A.J. Wilson, Jr. 1971. Polychlorinated biphenyl absorbed from sediments by fiddler crabs and pink shrimp. Nature, 231, p. 50.

PCB's, in particular, Aroclor 1254, have been noted in water, sediment and biota from Escambia Bay, Florida. Studies revealed high concentrations of this contaminant in three shrimp species and fiddler crabs. The largest accumulations of Aroclor 1254 were in the sediments and in most cases, the amount of this PCB in individual crab or shrimp hepatopancreas was directly related to the amount in the sediments.

Nimmo, D.R., D.J. Hansen, J.A. Couch, N.R. Cooley, P.R. Parrish and J.I. Lowe. 1975. Toxicity of Aroclor 1254 and its physiological activity in several estuarine organisms. Archives of Environmental Contamination and Toxicology, 3(1): 22-39.

The occurrence of high concentrations of a PCB (Aroclor 1254) in the Pensacola estuary prompted field and laboratory studies by the Gulf Breeze Environmental Research Laboratory (EPA). Monitoring of the estuary indicates the chemical is present in all components--particularly in sediments and fishes. Residues appear to be diminishing in sediments. Toxicity tests show estuarine species sensitive at ppb concentrations in water, with a ciliate protozoan (Tetrahymena pyriformis W), shrimps (Penaeus duorarum, P. aztecus, and Palaemonetes pugio), and a fish (Fundulus similis), affected at or near 1.0 ppb. Tissue concentrations of Aroclor 1254 similar to those found in natural populations of shrimps from the contaminated estuary were successfully duplicated in laboratory experiments. Shrimps also concentrated the PCB from very low concentrations (0.4 ppb) in the water. Three estuarine species demonstrated pathologic changes at tissue and cellular level after chronic exposure to the chemical. Oysters (Crassostrea virginica) developed abnormal infiltration of leukocytes in the connective tissue, spot (Leiostomus xanthurus) developed fatty changes in their livers, and shrimp (Penaeus duorarum) developed crystalloids in hepatopancreatic nuclei.

#### Author's Abstract

Nimmo, D.R., R.R. Blackman, A.J. Wilson, Jr. and J. Forrester. 1971. Toxicity and distribution of Aroclor 1254 in the pink shrimp Penaeus duorarum. Marine Biology, 11: 191-197.

The polychlorinated biphenyl Aroclor 1254 was released in an accidental leakage of heat-exchange fluid from an industrial plant, into the Escambia River, near Pensacola, Florida, USA. This material was carried downstream, and is now found in the fauna of Escambia Bay and its contiguous waters, prime nursery areas for fishes and invertebrates such as penaeid shrimp. The significance of pollution by this chemical was assessed by establishing toxicity levels, determining routes of entry, and investigating its movement and distribution in various tissues of shrimp under controlled conditions in the laboratory. Aroclor 1254 added to the water was toxic to the juvenile pink shrimp Penaeus duorarum at a concentration of 1.0 part per billion within 15 days, but was less toxic to adult pink shrimp. Shrimp obtained the contaminant from water and food and concentrated it to 510.0 parts per million in the hepatopancreas. Aroclor 1254 residue data from shrimp collected in the estuary are included in the study.

#### Author's Abstract

Nisbet, I.C.T. and A.F. Sarofin. 1972. Rates and routes of transport of PCBs (polychlorinated biphenyls) in the environment. *Environmental Health Perspectives*, 1: 21-38.

This paper summarizes the fragmentary knowledge available about production, uses, and losses of PCB's in the environment. It discusses only production and uses within North America, and distribution of PCB residues in North America and adjacent seas.

Peakall, D.B. 1975. PCB's and their environmental effects. *CRC Critical Rev. Environ. Control*. 5(4): 469-508.

In this article, an attempt is made to assess the biological impact of PCB's, both on man and other creatures that inhabit this planet. The information on the production and usages of these materials is briefly reviewed, followed by a more detailed look at levels found in various types of organisms in various parts of the world. This information is used to consider the routes and rates of transfer of these materials through the ecosystem and their biological magnification during these processes. The physiological effects of PCB's are then considered, and their likely importance is assessed by comparison with existing environmental levels.

#### Modified Author's Introduction

Peakall, D.B. and J.L. Lincer. 1970. Polychlorinated Biphenyls. *BioScience*, Vol. 20, No. 17, pp. 958-964.

The structural and physical properties, uses, analytical methods, toxicology, levels in nature, and biological magnification of PCB's, and the ratio of DDT to PCB in the environment are summarized. Although nothing is known about the biological decomposition of PCB's, it is likely that they are more stable than DDT and its metabolites and thus have a tendency to accumulate up the food chain. No figures on the amount of these materials produced annually are available. Analysis of PCB's has been carried out by means of a combination of high resolution gas chromatography and mass spectrometry. Nitration and saponification have been used to separate PCB's from other residues for analysis. Although several studies have been carried out on the toxicology of PCB's, toxic levels are still largely undefined. Studies have shown, however, that there are striking alternations in the internal organs of some mammals and birds. Data taken from several studies indicate that the PCB's are capable of biological magnification in the food chain. Because of the apparent danger of these materials it is necessary to discover the major sources of their escape into the environment. Sixty-two references have been cited in this summary. [abstract from PCB in water - a bibliography.]

Sanders, H.O. and J.H. Chandler. 1972. Biological magnification of a polychlorinated biphenyl (Aroclor 1254) from water by aquatic invertebrates. *Bulletin of Environmental Contamination and Toxicology*, 7(5): 257-263.

The purpose of this study was to determine the rate of accumulation and biological magnification of  $^{36}\text{Cl}$ -labeled Aroclor 1254 from water by eight species of aquatic invertebrates. The invertebrates were exposed to Aroclor 1254 at concentrations less than 3 ppb, which is similar to levels detected in the water of Escambia Bay, Florida. In addition to measurement of accumulation, scud exposed to Aroclor 1254 were analyzed by gas-liquid chromatography to investigate potential shifts in residue composition which may have occurred as a result of metabolism.

#### Author's Introduction

Stalling, D.L. and F.L. Mayer. 1972. Toxicities of PCB's to fish and environmental residues in fish. *Environmental Health Perspectives*, 1: 159-164.

Analyses of 40 fish (cross-check sample) from the 1970 National Pesticide Monitoring Program were made for PCB's. Chronic and acute toxicity studies on aquatic organisms were reviewed. The highest concentrations of PCB residues in freshwater fish occur in rivers which are associated with industrialized areas.

Wildish, D.J. and V. Zitko. 1971. Uptake of polychlorinated biphenyls from sea water by Gammarus oceanicus. *Marine Biology*, 9(3): 213-218.

The uptake of a polychlorinated biphenyl preparation containing 5-7 chlorine atoms per molecule, solubilized in a nonionic surfactant in sea water, by Gammarus oceanicus was measured spectrophotometrically. Uptake occurred in living animals across the general integument. It is suggested that uptake rates are dependent upon the total surface area of the integument, although no accurate method of determining this is known. The rate of uptake decreased after 4-6 hr exposure and uptake was dependent upon concentration of polychlorinated biphenyls in sea water. The stage of the intermolt of G. oceanicus did not affect uptake rates.

Young, D.R. and I.S. Szpila. 1975. Decreases of DDT and PCB in mussels. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project, pp. 123-126.

Numerous studies by this Project and other researchers have documented the extent of marine contamination by DDT wastes off southern California. The intertidal mussel, Mytilus californianus, appears to have rather accurately reflected decreases in the input of total DDT to the coastal ecosystem. These studies have further demonstrated the mussel's usefulness as an indicator organism for chlorinated hydrocarbon contamination of nearshore waters. The study results also indicate that local annual inputs and biological concentrations of PCB are decreasing less rapidly than are those for DDT.



## EFFECTS OF TRACE METALS: MERCURY AND CADMIUM

Bothner, M.H. 1973. Mercury: Some aspects of its marine geochemistry in Puget Sound, Washington. Ph.D. Thesis, University of Washington, Department of Oceanography, Seattle, 126 pp.

Sediment cores collected periodically at the same stations from 1970 until 1973 show that the level of mercury in sediments is decreasing with time since the high discharge of mercury from a chlor-alkali plant has stopped. The rate of mercury loss appears to follow first order kinetics with a half-life of 1.3 years, in sediments which are generally oxidizing and which had initial mercury concentrations of 2-10 ppm.

A strong covariant relationship was observed between the mercury concentration in suspended matter and in solution. Selective leaching experiments designed to show the important binding sites for mercury in sediments indicated that most of the mercury is associated with oxidizable organics.

Calabrese, A. and D.A. Nelson. 1974. Inhibition of embryonic development of the hard clam Mercenaria mercenaria, by heavy metals. Bulletin of Environmental Contamination and Toxicology, 11(1): 92-97.

Heavy metals have long been recognized as serious pollutants of the aquatic ecosystem, with deleterious effects on the associated organisms. Limited information is available for marine organisms and those studies that have been reported deal primarily with adult organisms; relatively little is known about the effects of metal on invertebrates, especially their embryonic stages.

With the development of rearing techniques for bivalve mollusks in the laboratory, further incentive has been provided for studies on the effects of pollutants on embryos of shellfish. The present study was undertaken to determine the effect of mercury, silver, zinc, nickel and lead on the survival and subsequent development of embryos of the hard clam, Mercenaria mercenaria.

Childs, E.A., and J.N. Gaffke. 1973. Mercury content of Oregon groundfish. U.S. National Marine Fisheries Service, Fisheries Bulletin, 71(3): 713-717.

The mercury content of Oregon groundfish was determined. The mercury content of rex sole, Glyptocephalus zachirus; Dover sole, Microstomus pacificus; petrale sole, Eopsetta jordani; English sole, Parophrys vetulus; sand sole, Psettichthys melanostictus; starry flounder, Platichthys stellatus; canary rockfish, Sebastes pinniger; flag rockfish, Sebastes rubrivinctus; yellowtail rockfish, Sebastes flavidus; rougheye rockfish, Sebastes aleutianus; sablefish, Anoplopoma fimbria; lingcod, Ophiodon elongatus; Pacific hake, Merluccius productus; and arrowtooth flounder, Atheresthes stomias; was significantly lower than 0.50 ppm mercury. All spiny dogfish, Squalus acanthias, samples contained

>0.50 ppm. No highly significant relationship in those species appropriately examined between (a) catch location, (b) time of catch, (c) weight and length of fish, or (d) sex and mercury content was observed.

#### Author's Abstract

Greclius, E.A. 1974. The marine geochemistry of arsenic and related elements in Puget Sound. Ph.D. Thesis, University of Washington, Department of Oceanography, Seattle, 133 pp.

In this thesis the fluxes of arsenic through Puget Sound by determining its input rates from various sources is estimated. Concentration profiles of arsenic and antimony in sediment cores are included. No consistent pattern of accumulation of these metals in higher trophic levels was observed, but methylated forms of arsenic were found in kelp, plankton and shrimp.

Greclius, E.A., M.H. Bothner and R. Carpenter. 1975. Geochemistries of arsenic, antimony, mercury, and related elements in sediments of Puget Sound. Environmental Science and Technology, 9(4): 325-333.

The natural distributions of arsenic, antimony, mercury, chromium, cobalt, iron, aluminum, and carbon in the surface sediments of Puget Sound are perturbed by two major anthropogenic sources of trace metals: a copper smelter near Tacoma, Wash., that discharges large amounts of arsenic and antimony, and a chlor-alkali plant in Bellingham, Wash., which, in the recent past, discharged significant amounts of mercury. Arsenic and antimony inputs from the smelter over the past 80 years are evident in sediment cores whose accumulation rates have been determined by the lead-210 technique. An arsenic budget for Puget Sound reveals the importance of atmospheric input resulting from smokestack emissions of the smelter. Chemical extraction studies of sediments showed that more than 82% of the mercury was associated with easily oxidizable organic matter, whereas about 50% of both arsenic and antimony was associated with extractable iron and aluminum compounds.

#### Author's Abstract

Eisler, R., G.E. Zarogian, and R.J. Hennekey. 1972. Cadmium uptake by marine organisms. Fisheries Research Board of Canada, Journal, 29(9): 1367-1369.

Adults of killifish Fundulus heteroclitus, scallop Aquiptecten irradians, oyster Crassostrea virginica, and subadult lobsters Homarus americanus were immersed for 21 days in flowing seawater containing 10 ug/liter of cadmium as  $\text{CdCl}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$ . Cadmium residues in whole animals and selected tissues were consistently higher in exposed organisms than controls; edible portions of treated lobster (muscle), scallop (adductor muscle), and oyster (whole animal) contained more cadmium per unit wet weight than controls by 25%, 19%, and 352%, respectively.

#### Author's Abstract

Fagerstrom, T. and B. Ansell. 1973. Methyl mercury accumulation in an aquatic food chain. A model and some implications for research planning. *Ambio*, 2(5): 164-171.

Methyl mercury accumulation in fish is theoretically studied by means of a mathematical model for a three-step food chain. The model assumes gain of methyl mercury in proportion to intake of oxygen and food, these inturn being size-dependant. Some properties of the model are analyzed with the specific aim of getting guidance for further research activities. This analysis lends, quantitatively, support to the belief that direct uptake of methyl mercury from water is the most important subject for further study.

#### Author's Abstract

Fowler, B.A., D.A. Wolfe and W.F. Hettler. 1975. Trace metal uptake and toxicity to shellfish. Conference on Heavy Metals in the Environment II., In: Environmental Health Perspectives, Vol. 10: 262-263.

The relationship between uptake and toxicity of trace metals to shellfish is of interest because these organisms are an important food source and human trace metal poisonings have occurred through their consumption. An understanding of how cells of marine invertebrate tissues handle trace metals in comparison with mammalian cells is also of scientific value.

In the current study, randomly selected specimens of the clam, Mercenaria mercenaria, and the oyster, Crassostrea virginica, were placed in sea water solutions (26°C and 35% salinity) containing 0, 0.1, 1, or 10 ppm  $Hg^{2+}$  or  $Cd^{2+}$ . The experiment was terminated for each element after half of the animals in the 10 ppm dose groups exhibited gaping valves. Cross sections of the animals were studied by light microscopy and portions of the mantles by electron microscopy. Heavy mortality occurred in oysters of the high dose groups after about 3 days of  $Cd^{2+}$  or  $Hg^{2+}$  exposure. This effect was not seen in high dose clams until 5 days with  $Hg^{2+}$  and 7 days with  $Cd^{2+}$ . The most readily detectable histologic changes characterized by clumping nuclear material and cytoplasmic rarification were observed in columnar epithelial cells lining the gut of each species. Electron microscopy of mantle epithelial cells disclosed a dose-dependant increase in electron dense cytosomes within these cells in  $Hg^{2+}$ -treated clams. The cytosomes were not observed in  $Cd^{2+}$ -treated animals or in oysters exposed to  $Hg^{2+}$ . Energy-dispersive x-ray microanalysis disclosed the presence of high iron concentrations on reaction to mercury within these cytosomes.

#### Author's Abstract

Fowler, S.W. and G. Benayoun. 1974. Experimental studies on cadmium flux through marine biota. Comparative studies on food and environmental contamination, Proceedings Series., Vienna: Int. Atomic Energy Agency, pp. 159-178.

The role of mussels (Mytilus galloprovincialis) and benthic shrimp (Lysmata seticaudata) in the cycling of Cd in the marine environment was examined. Concentration measurements were made by atomic absorption spectrophotometry and anodic stripping voltammetry. A steady state between water and the organisms was not reached after 2 mo. Concentration factors were 130 and 600 in whole mussels and shrimp, respectively. Concentration factors based on stable Cd concentrations were several times higher, noting incomplete equilibration between  $^{109}\text{Cd}$  and stable Cd in the organisms. Highest concentrations for both species were in the viscera. Uptake of Cd was directly proportional to the Cd content in seawater. Measurements were taken at 8°C, 13°C, and 22°C. Cadmium uptake increased in shrimp at higher temperatures but not in the mussels. Cadmium flux is a relatively slow process in mussels and shrimp. Animals retain a significant fraction of the accumulated metal for a relatively long time.

Keckes, S. and J.K. Miettinen. 1972. Mercury as a marine pollutant. In: Ruivo, M. (ed), Marine Pollution and Sea Life, Fishing Trading News (books) Ltd., London: 276-282.

The detrimental compounds introduced into the seas and oceans cover a wide range of organic and inorganic substances. Among the inorganic substances are the heavy metals, notably mercury and lead, to which organisms are especially sensitive because they interfere with vital biochemical processes.

The biogeochemistry of mercury is considered; its occurrence and accumulation by fish and other marine organisms. The biological effects of mercury are also discussed.

#### Author's Abstract

Klein, D. and E. Goldberg. 1970. Mercury in the marine environment. Environmental Science and Technology, 4: 765-768.

Mercury levels in coastal marine organisms are several orders of magnitude greater than in comparable volumes of seawater. Also, higher values of mercury are found in sediments near sewer outfalls as compared to similar deposits further removed. The dispersion of this toxic pollutant by marine organisms and by man has already had serious consequences.

#### Author's Abstract

Laumond, F., M. Neuburger, D. Donnier, A. Fourcy, R. Bittel and M. Aubert. 1973. Experimental investigations, at laboratory, on the transfer of mercury in marine trophic chains. Rev. Int. Oceanogr. Med., 31/32: 47-53.

The transfer of Hg in a pelagic chain (plankton, fish) and in a neritic chain with molluscs (plankton, mussel) was studied. The first trophic level was contaminated with water and the second simultaneously with water and food (first trophic level) as in natural conditions. Hg<sub>2+</sub> at subtoxic concentrations was introduced into water either as Hg<sub>2+</sub> ions or associated with natural and artificial organic compounds which are found in the oceanic environment and in effluents. Determinations of Hg were done by extraction titration with dithizone; the flameless atomic absorption technique is being perfected. Some results were checked by neutron activation. In the fixed experimental conditions the transfer factors of Hg from sea water to fish or molluscs were about 50 and 3000.

#### From Biological Abstracts

Lloyd, R. 1965. Factors that affect the tolerance of fish to heavy metal poisoning. In: Biological Problems in Water Pollution, Third Seminar, 1962, Washington, D.C. (GPO), Public Health Service, Publc. No. 999-WP-25. pp. 181-187.

Factors such as temperature and the concentration of dissolved gases and calcium in the dilution water had been shown to modify the amount of heavy metal needed to kill fish. These experiments, however, had only shown the qualitative importance of these factors; there were few quantitative results.

The work described in this paper represents an attempt to place on a quantitative basis some of the effects that the chemical and physical nature of the water have on the toxicity of the heavy metals to fish, so that a more accurate estimation of the application factor can be made.

McDermott, D.J. and M.J. Sherwood. 1975. Metals in diseased Dover sole. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project. pp. 47-49.

The purpose of this research was to investigate the association of fin erosion in Dover sole with exposure of the species to high levels of trace metals in bottom sediments off the Palos Verdes Peninsula. Concentrations of 25 trace metals and major cations in several tissues from Dover sole with and without fin erosion from the Palos Verdes shelf and from healthy Dover sole from the control region off Dana Point were examined. The analyses were performed by optical emission spectrography. Samples of muscle, kidney, gonad, and skin (from both the blind and eyed sides) were taken from ten individuals in each of the three categories. Preliminary results for the levels of cadmium, chromium, copper, and lead and for calcium, magnesium, and sodium in these samples were available at the time of this report.

McDermott, D.J. and D.R. Young. 1974. Trace metals in flatfish around outfalls. Coastal Water Research Project Annual Report - 1974, Southern California Coastal Water Research Project. pp. 117-121.

Seven trace metals, silver, cadmium, chromium, copper, nickel, lead and zinc are discussed in relation to Dover sole populations near outfalls. The main question being considered is whether or not flatfish living in contaminated sediments concentrate these metals above normal tissue levels. Concentration of the above metals from gonads, flesh and livers from control and test fish were compared.

Matsumura, F., Y.G. Doherty, K. Furukawa and G.M. Boush. 1975. Incorporation of  $^{203}\text{Hg}$  into methylmercury in fish liver: Studies on biochemical mechanisms in vitro. Environmental Research 10: 224-235.

It was found that livers of all fish species particularly pelagic species studied were capable of transforming mercuric ion into methylmercury in vitro. These factors involved in the process of methylmercury formation from  $\text{Hg}^{2+}$  ion in the fish liver were studied.

The methylation activities were not destroyed by either heat or uv and visible light irradiation treatments. It was thus concluded that the reaction(s) studied here was not mediated by methylcobalamine. Mersalyl, a SH inhibitor, could, however, abolish most of the methylation reaction.

#### Author's Abstract

Nevissi, A., D.D. Huntamer, S.J. Olsen, R.B. King, C.E. Vick and W.R. Schell. 1976. Trace contaminants from dredge spoils in Elliott Bay. In: 1975 Research in Fisheries, Annual Report on the College of Fisheries, University of Washington, Contribution No. 444.

This project was initiated in February, 1975, to measure the increase in trace contaminants (heavy metals, particulates, etc.) in Central Puget Sound, resulting from the dredging of 250,000 cubic yards of sediment from the Duwamish River estuary and depositing it off Four Mile Rock in Elliott Bay, a location near sites under study prior to the dumping of the Duwamish sediments. This program is being conducted for the Municipality of Metropolitan Seattle (METRO) and the Corps of Engineers by the College of Fisheries, Department of Oceanography, and two oceanographic consultant companies, with the College assuming the lead role. The physical circulation and transport of water in Elliott Bay has been simulated, using a scale-model of Puget Sound, and measured by drogues in the field. The water quality parameters of temperature, specific conductivity, pH, dissolved oxygen and light transmission were measured during the drogue studies. Profiles of

suspended particulates have been made from the results of analyses of water samples collected with the Battelle large-volume water sampler and with Niskin bottles during the drogue measurements. These samples, as well as plankton samples that have been collected near the spoils deposition site and at control stations, are being analyzed for trace metals. In addition, cores have been collected to determine the areal dispersion of the dredge material. It is expected that the distribution of the dredged spoils from the disposal site at Four-Mile Rock can be determined from these data.

#### Author's Abstract

Pringle, B.H., D.E. Hissong, E.L. Katz and S.T. Mulawka. 1968. Trace metal accumulation by estuarine mollusks. J. Sanit. Engng. Div. Am. Soc. Civ. Engrs., 94(SA3): 455-475.

Mollusks in the natural estuarine environment appear to accumulate trace metals at different rates and attain tissue levels according to the environmental concentration of the particular metal, the temperature, the species concerned, as well as the physiological activity of the animal itself.

Riley, J.P. and D.A. Segar. 1970. The distribution of the major and some minor elements in marine animals I. Echinoderms and Coelenterates. Marine Biological Association, U.K., Journal, 50: 721-730.

A scheme employing atomic absorption spectrophotometry, flame photometry and colorimetry has been developed for the determination of Ag, Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Sn, Sr and Zn in marine animals. The distribution of these elements in 7 echinoderms and 2 coelenterates has been studied. Figures are presented for their concentrations in the dissected parts of Echinus esculentus, Spatangus purpureus and Asterias rubens. Trace metals are most strongly concentrated in the digestive parts of the organisms, less so in the gonads, and least in the skeletal tissues. Of these metals zinc attains the highest concentration, in some instances copper, nickel, cadmium are also quite strongly concentrated.

#### Author's Abstract

Schell, W.R. Ongoing Research. Heavy Metal Analyses from Puget Sound Biota and Sediments. For, Environmental Protection Agency, In: 1974 A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters.

This contract requires the analyses of approximately 35 samples of Puget Sound fish, plankton, anemone, sea cucumber and other biota and sediment for up to 12 heavy elements. Samples can consist of a species sub-sample such as liver, viscera, bone or muscle, and samples will be analyzed by best technique, either neutron activation analysis or atomic absorption spectroscopy using both wet and dry ashing procedures. All biota and sediment samples are from Puget Sound waters in the general vicinity of the ASARCO Tacoma, Washington Copper Smelter but will contain control samples taken from the Colvos Passage area of Puget Sound.

#### Author's Abstract

Schell, E.R., A. Nevissi, D.D. Huntamer, A.F. Johnson, T.A. Jokela, R.B. King, R.T. Lusk, S.J. Olson, and C.E. Vick. 1976. Heavy metals in central Puget Sound. (Abstract). In: 1975 Research in Fisheries, Annual Report on the College of Fisheries, University of Washington, Contribution 444, p. 36.

This program is part of a general study to establish base line values for the amounts of lead, mercury, and other heavy metals in the biota and waters of Lake Washington, Puget Sound and coastal waters of Washington. Sources of heavy metals in aquatic environmental are soil erosion, stream runoff, leaching from soils and sediments, and effluents that result from industrialization and urbanization. Once the base line values for the heavy metals have been established, identification of their source--natural or man-produced--and knowledge of their pathways through the ecosystem are necessary to fully evaluate their impact on man and the environment. The past history of the introduction and accumulation of heavy metals in aquatic environments may lead to rational control of heavy metals in the future.

#### Shortened Author's Abstract

Segar, D.A., J.D. Collins and J.P. Riley. 1971. The distribution of the major and some minor elements in marine animals II. Molluscs. Marine Biological Association, U.K., Journal, 51: 131-136.

A study had been made of the distribution of 6 major and 13 trace elements in the shells and entire soft parts of 11 species of mollusc from the Irish Sea and in those of one freshwater species. Values are also presented for the occurrence of these elements in the various organs of Pecten maximus and Modiolus modiolus. All the trace metals are considerably more enriched in the soft parts of the organisms than in the marine environment. The highest concentrations of these elements are found in the digestive organs and gills, and the lowest concentrations are found in the shells.

#### Author's Abstract



Sherwood, M.J. 1975. Laboratory experiments exposing Dover sole to contaminated sediments. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project. pp. 41-42.

Studies were carried out to determine if fins from healthy Dover sole are directly damaged by contact with contaminated bottom sediments. This experiment, which is still in progress, tests at least two of the possible causative agents associated with contaminated sediments, grain size and roughness and external exposure to pesticides and trace metals.

## LIFE HISTORIES AND DISTRIBUTIONS OF INVERTEBRATES USED IN THE STUDY

SHRIMP: Pandalus jordani, P. borealis, P. platyceros

Allen, J.A. 1959. On the biology of Pandalus borealis Krøyer, with reference to a population off the Northumberland Coast. Marine Biological Association, Journal. 38: 189-220.

Data on the distribution of Pandalus borealis have been brought up to date, and the factors controlling its distribution (temperature, salinity, substratum and depth) are discussed. An account of the biology of the population off the Northumberland coast is given and compared with accounts of work on other populations. Knowledge of the biology of this species now extends over the entire north-south range in the eastern Atlantic. Details of the histology and development of the gonads are given, particularly with respect to the development of the ova and to sex reversal. Sex changes in the gonad are considered in relation to changes in external form. The growth rate of the North Sea prawn is described and compared with that of other populations.

Barr, L. 1970. Alaska fishery resources--The shrimps. U.S. Fish and Wildlife Service, Fisheries Leaflet 631, 10 pp.

The five commercially important shrimp of Alaska belong to the family Pandalidae; the most important is the pink shrimp, Pandalus borealis.

The complicated life histories of these shrimp are all similar. The shrimp develop first as males and after several years transform into females, which they remain for the rest of their lives.

The Alaska Department of Fish and Game and the Bureau of Commercial Fisheries are studying shrimp. They are sampling the commercial catch, trying to improve the product, and conducting exploratory fishing and biological research.

### Shortened Author's Abstract

Barr, L. 1970. Diel vertical migration of Pandalus borealis in Kachemak Bay, Alaska. Fisheries Research Board of Canada, Journal. 27: 669-676.

Catches of Pandalus borealis by surface-to-bottom pot fishing in Kachemak Bay, Alaska, showed that this species was distributed in large numbers throughout the water column at night and suggested a diel vertical migration. The shrimp apparently left the vicinity of the bottom about dusk and returned about dawn; the apparent length of time they were off bottom was directly related to the length of the night. Bottom trawling clearly showed lower availability of P. borealis on bottom at night than during the day. Catches of shrimp by pot fishing and trawling indicated that small P. borealis have a greater tendency to migrate vertically than the larger individuals.

### Author's Abstract

Butler, T.H. 1971. A review of the biology of the pink shrimp, Pandalus borealis Krøyer 1838. Proc. Conference on the Canadian shrimp fishery, Canadian Fish. Reports No. 17. pp. 17-24.

Important and relevant papers on the biology of the species are reviewed. Topics of major interest are: distribution, ecology, age and growth, reproduction (sex change), spawning and hatching, fecundity, age at maturity, migration feeding, and abundance related to temperature. Other minor, yet pertinent, items include: taxonomy, length-weight relationship, larval stages, and parasites. Some special emphasis is placed on studies in the western Atlantic Ocean.

Butler, T.H. 1970. Synopsis of biological data on the prawn Pandalus platyceros Brandt, 1851. F.A.O. Fish. Report. 57(4): 1289.

This synopsis includes such categories as identity, distribution, binomics and life history, population (stock), and exploitation of the shrimp Pandalus platyceros.

Butler, T.H. 1964. Growth, reproduction, and distribution of pandalid shrimps in British Columbia. Fisheries Research Board of Canada, Journal. 21(6): 1403-1452.

The ranges, habitats, and commercial importance are described for nine species of the family Pandalidae: Pandalopsis dispar, Pandalus jordani, P. borealis, P. platyceros, P. hypsinotus, P. danae, P. montagui tridens, P. stenolepis, P. goniurus. A key for their identification is given. Over 27,400 specimens were sampled, using trawl and trap gear, mostly from the Strait of Georgia. Pandalopsis dispar is a male at 1½ years, attaining a total length of 136 mm and body weight of 6.5 g; at 30 months, in the female phase, the length is 169 mm and weight 16.3 g. Pandalus jordani matures as a male, and to a lesser extent a female, at about 18 months, reaching a length of 105 mm and weight of 3.8 g; at 2½ years all are in the female phase, averaging 118 mm in total length and 5.8 g in body weight. P. platyceros is first a male at 1½ years, attaining a length of 140 mm and weight of 14.2 g; most remain as males for another year, and at 3½ years the total length is 180 mm and weight 35.5 g. Pandalus hypsinotus matures as a male, and to some extent as a female, at about 1½ years, at a total length of 124 mm and weight of 10.3 g; at 30 months the length is 130 mm and weight 12.7 g. Almost as many females as males of P. borealis mature at 1½ years, attaining a length of 95 mm and weight of 3.2 g; at 30 months, in the female phase, the length is 119 mm and weight 6.1 g. Pandalus danae matures first as a male, and to some extent as a female, at 1½ years, reaching 88 mm in length and 4.4 g; in the female phase, at 2½ years the length of 105 mm and weight 8.5 g. Growth of P. montagui tridens, P. stenolepis, and P. goniurus is uncertain, but all undergo sex change. Growth as related to habitat and early maturing of females as related to geographic and bathymetric ranges are discussed.

Author's Abstract

Chew, K.K., J.W. Wells, D. Holland, D.H. McKenzie and C.K. Harris. 1972. January size frequency distribution of Pandalopsis dispar and Pandalus platyceros trawled in Dabob Bay, Hood Canal, Washington from 1966 to 1971. (Abstract). Proc. National Shellfisheries Association, Vol. 62: 2-3.

The size frequency of both males and females of Pandalopsis dispar and Pandalus platyceros was presented and discussed. Even though samples were taken during the same month each year, there were wide variations in the annual distributions.

Only the length-weight relationship of Pandalus platyceros was presented. As expected, the relationship was in the form of a curvilinear regression. After logarithmic transformation of the length-weight data for covariance analysis, the 1966, 1969, 1970 and 1971 lines followed a common slope, but possessed unequal means and thus could not be represented by one common line. No data were available for 1967 and the slope for the 1968 line was significantly different from all other data.

In addition, the bathymetric distribution for Pandalus platyceros was presented for the 1970 and 1971 data. By trawling at different depths and at different times of the day, we were able to determine the catch per unit of effort for the individual hauls. This species had a definite diel migration pattern; they were most numerous at shallow depths during the nighttime and at deep depths during the daytime.

#### Author's Abstract

Chew, K.K., D. Holland, J.W. Wells, D.H. McKenzie and C.K. Harris. 1974. Depth, distribution, and size of spot shrimp, Pandalus platyceros, trawled in Dabob Bay of Hood Canal, Washington from 1966 to 1971. Proc. Nat. Shellfisheries Assoc. 64: 28-32.

The January size frequency distribution of male and female spot shrimp (Pandalus platyceros) was presented and discussed. The females revealed more variability from year to year. There appeared to be two size groups of females in some years. The male size distribution was more consistent.

The 1966, 1968, 1969, 1970 and 1971 spot shrimp length-weight lines were compared and the similarities and differences from year to year were shown. Further, it was shown that this species of shrimp may have a diel migration pattern. Trawl hauls for 1970 and 1971 revealed they were found to be greatest in numbers at shallower depths during the nighttime and greatest in numbers at deeper depths during the daytime.

#### Author's Abstract

Dahlstrom, W.A. 1970. Synopsis of biological data on the ocean shrimp Pandalus jordani Rathbun, 1902. F.A.O. Fish. Rept. 57(4): 1377-1416.

This is a synopsis of the shrimp Pandalus jordani following the F.A.O. synopsis outline which consists of the major categories (1) Identity, (2) Distribution, (3) Binomics and Life History, (4) Population (stock), (5) Exploitation, and (6) Protection and Management.

Dow, R.L. 1973. Fluctuations in marine species abundance during climactic cycles. Mar. Technol. Soc. J. 7(4): 38-42.

Periodic abundance fluctuations of major commercial species (Homarus americanus, Placopecten magellanicus, Mya arenaria, Mercenaria mercenaria, Crassostrea virginica, Glycera dibranchiata, Nereis virens, Pandalus borealis) are identified with sea surface temperature changes associated with climactic cycles.

Fox, W.W., Jr. 1972. Dynamics of exploited pandalid shrimps and an evaluation of management models. Ph.D. Thesis, University of Washington, College of Fisheries. 193 pp.

The purpose of this study is to gain some understanding of the response to exploitation of a population with the life history characteristics of pandalid shrimps. To this end, first a review of the known life history characteristics of pandalid shrimps, their fisheries, and current management strategies is presented. Secondly, a review of traditional management models is presented and a simulation model is developed. Traditional management models and strategies are then evaluated utilizing data from the Kodiak pink shrimp fishery and the simulation model.

#### Shortened Author's Introduction

Fox, W.W., Jr. 1972. Shrimp resources of the northeastern Pacific Ocean. In: D.H. Rosenberg (ed.), A review of the oceanography and renewable resources of the northeastern Gulf of Alaska. Section 15, Inst. Mar. Sci., Univ. of Alaska, 26 pp.

This report concerns itself with the distribution of commercially important shrimp, their habitats and biology. The present exploitation is described along with management of the shrimp fisheries.

Gotshall, D.W. 1972. Population size, mortality rates, and growth rates of northern California ocean shrimp, Pandalus jordani, 1965 through 1968. California Department Fish and Game, Fisheries Bulletin, 155.

Sea surveys were initiated in the spring of 1965 to obtain estimates of population size, mortality rates, and growth rates of the northern California ocean shrimp population. From March 1965 through September 1968, nine surveys were conducted in a 270-square-mile area from off Mad River, California, north to Smith River, California. Four surveys were conducted in the 105-square-mile area off southern Oregon during 1967 and 1968. Estimates of the California population ranged from a low of 2.2 million pounds in the fall of 1966 to a high of 8.1 million pounds in the fall of 1967.

Survival rates, derived from natural mortality rates for ocean shrimp during their second winter of life, for the 1964 and 1965 year classes were 0.68 and 0.55, respectively. Lowest survival rates were obtained from the 1963 and 1964 year classes during their third winter of life. The highest fishing mortality rates were observed for shrimp during their third summer in the fishery. Survey data indicate a relationship between annual fishing mortality rates and total trawling hours expended by shrimp fishermen. Limited data suggest a relationship also exists between the number of spawners and 1-year-old recruits as well as the existence of a density dependent relationship between population size and survival of the incoming year class.

#### Shortened Author's Abstract

Haynes, E.B. and R. Wigley. 1969. Biology of the northern shrimp, Pandalus borealis, in the Gulf of Maine. Trans. Amer. Fish. Soc. 98(1): 60-76.

Northern shrimp from offshore waters in the Gulf of Maine were studied to determine their occurrence and to learn some major features of their life history. The area sampled extends from Nova Scotia, Canada, to Long Island, New York. Northern shrimp were found only in the western portion of the Gulf of Maine, where they were present throughout the year, and at two isolated localities southeast of Nova Scotia. Abundance was highest in moderate depths in the vicinity of Jeffrys and Cashes Ledges and southeast of Mount Desert Island, Maine, and lowest in the deeper, offshore areas in the west-central part of the Gulf. High water temperatures appear to limit the southward extension of this species off New England. Within the Gulf of Maine this shrimp occurs on fine-grained bottom sediments, such as clay, silty sand, and glacial till, which contain relatively large amounts of organic matter. Average life span is about  $3\frac{1}{2}$  years and may extend to  $4\frac{1}{2}$  years for a small portion of the population. Northern shrimp are protandric hermaphrodites, functioning first as males. Spawning is in August and September. Most of the shrimp spawn only once as females--about 20% at  $2\frac{1}{2}$  years of age, 70% at  $3\frac{1}{2}$  years, and 10% at  $4\frac{1}{2}$  years. The eggs remain attached to the pleopods for about 6 months and hatch in the spring (March and April). Egg-bearing females migrate from the deeper (offshore) waters to shallow (inshore) areas during the maturation period. It is the egg-bearing females, which are concentrated near the mouths of estuaries and other near-shore areas,

that make up the bulk of the commercial catch. The number of eggs per clutch increases with shrimp size and averages 2,400 (range, 800 to 3,400). Length-weight relations are similar for males and nonovigerous females; ovigerous females are about 1.4 g heavier for any given length than the nonovigerous ones. Growth rate of the Gulf of Maine population is faster at ages of 2 years and older than that of any other population of this species reported to date.

#### Author's Abstract

Ivanov, B.G. 1972. The geographical distribution of the northern shrimp, Pandalus borealis Kr. (Crustacea Decapoda). Proc. National Shellfisheries Association, Vol. 62: 9-14.

Pandalus borealis is an amphiboreal species of Pacific origin. Water current and distribution patterns of the shrimp are similar in the Atlantic and Pacific Oceans. P. borealis abounds at many different depths and temperatures throughout its range which suggests that these factors are of minor importance. The structure of water masses and presence of muddy substrates are of major importance in concentrating the species. High temperatures in southern waters limit distribution possibly by hyperaccelerating sexual development. Pandalid shrimps are protandric and this condition seems to prohibit their inhabiting shallow, tropical waters. Populations show different reproductive capacities by areas and are mapped.

#### Author's Abstract

Ivanov, B.G. 1969. The biology and distribution of the northern shrimp (Pandalus borealis Kr.) in the Bering Sea and the Gulf of Alaska. F.A.O. Fish Rept. 57(3): 799-810.

Explorations in the North Pacific in recent years have revealed considerable stocks of Pandalus borealis Kroyer in the Bering Sea and the Gulf of Alaska. Studies on size composition show that the shrimp catches are mostly made up of specimens aged between 1½ and 5½ years; a few survive to 6½ years. Size at first maturity (as males), at sex-change and at second maturity (as females) was also studied. The strength of different year-classes can be largely explained from the character of the first winter after hatching and the abundance of the parent year-classes.

Three ecological zones are recognizable within the area considered. Large concentrations of shrimps tend to form in the zone of interactions of two water masses rather than in waters of a particular temperature. Local circulations due to islands and bays help to prevent the dispersal of larvae to unfavourable areas.

#### Author's Abstract

Pearcy, W.G. 1972. Distribution and diel changes in the behavior of pink shrimp, Pandalus jordani, off Oregon. Proc. National Shellfisheries Association, Vol. 62: 15-20.

Beam trawl catches of pink shrimp (Pandalus jordani) during the day-time always exceeded catches at night at the same station during two cruises in 1969 and 1970. Diel differences also occurred in the size composition of shrimp. Females larger than 20 mm carapace length composed a larger percentage of the night than the day catches. The proportion of males, on the other hand, decreased in beam trawls made after dark. Thus, males showed a greater tendency to migrate off the bottom at night than females.

Migratory behavior was further substantiated by the fact that shrimp were caught in all of the midwater trawl collections during the nighttime but in none of the daytime collections.

An underwater camera was used to photograph shrimp at a station off Cape Foulweather in 1971. In general, both photographs and beam trawl catches indicated a high density of small shrimp, averaging 7 to 15 individuals per m<sup>2</sup>.

The results of plankton net tows in April suggested that postlarval shrimp were most abundant near the bottom.

#### Author's Abstract

Pearcy, W.G. 1970. Vertical migration of the ocean shrimp Pandalus jordani: A feeding and dispersal mechanism. California Fish and Game, 56(2): 125-129.

Ocean shrimp, mainly immature males, were common in nighttime midwater trawl collections off Oregon. They were captured every month of the year except May and June. Annual catches varied greatly at the same stations during 7 years.

Shrimp caught in midwater at night were foraging on euphausiids and copepods. The stomachs of shrimp caught in bottom trawls, on the other hand, contained benthos, but no identifiable pelagic animals. Besides being related to feeding behavior, vertical migration may enhance dispersal of shrimp.

#### Author's Abstract

Robinson, J.R. 1971. The distribution and abundance of pink shrimp (Pandalus jordani) off Oregon. Fish Commission of Oregon, Investigation Report. No. 8. 48 pp.



The objectives of this study were to obtain estimates of the standing crop and define distribution of pink shrimp off Oregon. We hoped to obtain these estimates within a short enough time span to minimize possible biases from mortality and migration within and between shrimp concentrations. We also hoped to obtain a series of estimates, seasonally, to record changes in distribution/abundance with time.

Other objectives were estimates of age and sex composition geographically and seasonally, and fecundity and time of spawning.

Our last objective was to correlate distribution and abundance of shrimp with depth and the type of bottom sediment. Systematic studies of the type of sediment on which shrimp are found were lacking even though the literature is full of references associating shrimp with green mud and sand strata.

#### Shortened Author's Introduction

Ronholt, L.L. 1963. Distribution and relative abundance of commercially important Pandalid shrimps in the NE Pacific Ocean. U.S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report. Fisheries No. 449. 28 pp.

Data resulting from exploratory fishing on 18 cruises of the Bureau of Commercial Fisheries exploratory fishing vessel John N. Cobb from 1950-60 were analyzed to determine the average catch of shrimp per unit of effort and per 10-fathom depth interval in each of four areas: Oregon and Washington; Southeastern Alaska, Central Alaska, and Alaska Peninsula. The five species of shrimp encountered were: Pandalus jordani, P. borealis, P. hypsinotus, P. platyceros, and Pandalopsis dispar. Gulf of Mexico shrimp trawls and West Coast beam trawls were the major gear used during the explorations.

#### Author's Abstract

Tegelberg, H.C. and H.M. Smith. 1957. Observations on the distribution and biology of the pink shrimp (Pandalus jordani) off the Washington coast. Washington Department of Fisheries, Fisheries Research Paper, 2(1): 25-34.

Exploratory fishing off the Washington coast by the John N. Cobb in October-November 1955 and March-April 1956 revealed the presence of commercial quantities of pink shrimp, Pandalus jordani. The better catches were made in depths of 60 to 85 fathoms, extending from southwest of Grays Harbor to the Queets River.

Measurements and the sex of 4,828 shrimp from the autumn samples and 4,464 shrimp from the spring samples were determined. Two size-groups were prominent in the autumn and three in the spring. Including the newly hatched group, at least four year-classes were in the water in April.

In the autumn, 37% of the females were egg-bearing as compared with 18% in the spring, but after April 16 the egg-bearing females disappeared from the catch. The average number of whole shrimp per pound varied from 100 to 166 in the autumn samples and from 96 to 214 in the spring samples. Although variations in size of the shrimp in individual drags were significant, no consistent differences were evident by depth or by geographical area.

#### Modified Author's Summary

CLAMS: Venerupis japonica, Prototheca staminea

Ellifrit, N., M.S. Yoshinaka and D. W. Coon. 1973. Some observations of clam distribution at four sites on Hood Canal, Washington. (Abstract). Proc. National Shellfisheries Association, Vol. 63: 7.

Personnel of the Bureau of Sport Fisheries and Wildlife, Division of River Basin Studies, conducted a study of intertidal shellfish populations at 4 sites on Hood Canal in March and April, 1972. The purpose of the study was to determine whether bulkheads and attendant fill in the upper intertidal levels have an effect upon shellfish.

Samples were collected along 4 transects perpendicular to the shoreline at each site. Two transects were located in front of a bulkhead and 2 on an adjacent natural beach. Sampling stations were located at 10 ft intervals on the transects. A sample of substrate  $\frac{1}{2}$  m<sup>2</sup> and approximately 8 in deep taken at each station was sorted through 1 in and  $\frac{1}{2}$  in mesh screens, and all clams were saved for classification and measurement.

At 3 of the sites more than twice as many clams were found on natural beaches than on bulkheaded beaches. There was significant difference between bulkheaded and natural beaches at 2 sites in number of Japanese littleneck clams, Venerupis japonica, found in the upper intertidal area. There was also a trend toward differences in size and distribution. Clams inhabiting lower intertidal levels did not seem to be affected by bulkheads.

Several hypotheses for the differences were proposed. The most probable explanation is the change in current patterns associated with bulkheads which result in less favorable conditions for settling and survival of clam larvae. These conditions also may cause a reduction in availability of nutrients and food.

Author's Abstract

Goodwin, C.L. 1973. Distribution and abundance of subtidal hardshell clams in Puget Sound, Washington. Washington Department of Fisheries, Tech. Rep. No. 14. 81 pp.

This study was conducted because of the increasing importance of hard-shell clams to sport and commercial interests in Puget Sound. The field work was completed between July 1967 and the fall of 1971. Included in the report are findings of extensive diver surveys of stocks of subtidal hard-shell clams in Puget Sound. The relationship between abundance and several environmental factors is discussed. The merits of two types of commercial clam harvesters are also included.

Herrmann, R.B. 1973. Clam distribution and abundance in Grays Harbor as related to environmental factors. (Abstract). Proc. National Shellfisheries Association, Vol. 67: 7.

From 1967-69 surveys were conducted in Grays Harbor to determine the distribution and abundance of native and introduced clams. Nine species including 4 softshell-type and 5 hardshell-type clams occur in the bay. The softshell clams, especially Mya arenaria, are the most numerous and have the widest distribution, occurring from within a mile of the bay mouth eastward to the mouth of the Chehalis River at Hoquiam. The hardshell-type clams occur mostly in the western portion of the bay. Clinocardium nuttalli has the widest distribution in this group, occurring from the mouth of the bay east to Johns River and Neds Rock.

Clam distributions are discussed in relation to seasonal levels of salinity and pulp mill effluents. Persistent conditions of low salinities throughout most of the bay in colonization of greater portions of the bay by hardshell clams. Summer pulp effluent levels have had little apparent effect on the colonization of softshell type clams in the eastern bay areas, where highest levels occur.

Author's Abstract

Holland, D.A. and K.K. Chew. 1974. Reproductive cycle of the Manila clam (Venerupis japonica) from Hood Canal, Washington. Proc. National Shellfisheries Association, Vol. 64: 53-58.

Seasonal gonadal changes were observed histologically in samples of the Manila clam (Venerupis japonica, Deshayes) collected from Misery Point and Big Beef Harbor in Hood Canal, Washington between October 1970 and November 1971. With few exceptions, ripe clams first appeared in May-June and most active spawning occurred in July. Spawning was nearly completed in October. Sexual maturation began at a shell length of 5 mm and spawning at 20 mm and over.

Author's Abstract

Houghton, J.P. 1973. The intertidal ecology of Kiket Island, Washington, with emphasis on age and growth of Prototheca staminea and Saxidomus giganteus (Lamellibranchia: Veneridae). Ph.D. Thesis, University of Washington, College of Fisheries, Seattle. 179 pp.

In this study an effort was made to describe baseline conditions within the existing intertidal communities of Kiket Island. The primary objectives were: (1) establishment of as complete a species list of the intertidal macroflora and macrofauna of the Island as possible; (2) qualitative and quantitative description of the abundance and distribution of these macroorganisms and seasonal

variations therein; (3) investigation of the age and growth characteristics of the native littleneck clam (Prototheca staminea) at various locations about the Island. The secondary objectives were: (1) collection of ecological data on invertebrate species found; (2) estimation of age and growth characteristics of edible bivalves less abundant than P. staminea, and (3) comparison of zonation patterns at Kiket Island with those reported in the literature for other Eastern Pacific areas.

#### Author's Introduction

Nosho, T.Y. 1971. The setting and growth of the Manila clam, Venerupis japonica (Deshayes), in Hood Canal, Washington. M.S. Thesis, University of Washington, College of Fisheries. 67 pp.

Spat collectors containing seven artificial substratum types were installed at two stations in Hood Canal, Washington: Big Beef Harbor and Point Whitney. Replicated Latin square arrays of the treatments were used to determine optimal substratum types in relation to setting and growth of spats. Additional collectors were installed in separated rows and collected at the end of each month from July through November, 1969, and from June through September, 1970, to secure information on recruitment and growth. Results disclose that setting density at Big Beef Harbor was about ten times over that at Point Whitney, which probably reflects differences in tidal height of the plots. Differences between treatments in relation to number and size (shell length) were not noticeable. Setting occurred each month during the sampling period July through November. Major spatfall occurred from June to October. At Big Beef Harbor, mean shell length increased from 2.5 mm in November, 1969, to about 22 mm in September, 1970. The influence of currents on setting and its implications in this experiment are discussed.

Population surveys were conducted at three beaches (the two aforementioned plus Fisherman Harbor) by means of sampling grids. Clams were aged by delineating year classes. Sigmoid growth estimates at four age stages were obtained by following growth of late sets in spat collectors and the shifting of modes within year classes. In Hood Canal, V. japonica exhibits good growth, attaining an average maximum length of 50 mm. An estimate of the mean length for each age stage is as follows: 24 mm after one year, 36 mm after two years, 40 mm after three years, and 44 mm after four years.

#### Author's Abstract

Nosho, T.Y. and K.K. Chew. 1972. The setting and growth of Manila clam, Venerupis japonica (Deshayes), in Hood Canal, Washington. Proc. National Shellfisheries Association, Vol. 62: 50-58.

Collectors containing seven artificial substratum types appeared to catch the spat of Venerupis japonica equally well at two study areas: Big Beef Harbor and Point Whitney. The density of clam set at Big Beef Harbor, the primary study area, was significantly higher than that at Point Whitney. The probable causes for this difference are presented. Big Beef Harbor samples were taken at the plus 2.0-2.5 foot tide level while those at Point Whitney were taken at about the plus 5.0 foot level. The major period of spawning occurred from May through September. Spatfall was heaviest from June through October.

Length frequency distributions of populations at three beaches (the two aforementioned plus Fisherman Harbor) were used to estimate growth and four age stages. The mean length at annual age increments was as follows: 24 mm after one year, 36 mm after two years, 40 mm after three years and 44 mm after four years.

#### Author's Abstract

Ohba, S. 1959. Ecological studies in the natural population of a clam, Tapes japonica, with species reference to seasonal variation in the size and structure of population and to individual growth. Biol. J. Ukyama University., 5( $\frac{1}{2}$ ): 13-42.

The present study deals with the natural population of the clam, Tapes japonica, one of the main foodshells in Japanese waters. There are many reports on this shell, especially from the standpoint of commercial fisheries, morphology, taxonomy, or autoecology. However, ecological analysis of the population of this clam in its natural habitats has been left rather obscure, therefore this report. Some results in the present study may be applied to other populations in different localities, if adequate consideration is taken of environmental factors, because differences in population characters are merely quantitative in many cases.

Paul, A.J. and H.M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, Prototheca staminea, in Galena Bay, Prince William Sound, Alaska. U.S. National Marine Fisheries Service Bulletin, 71(3): 665-677.

Specimens of the littleneck clam, Prototheca staminea, were collected in Galena Bay, Prince William Sound, Alaska, during the summer months of 1971 for a study of recruitment, growth, and distribution.

The average size of P. staminea in Galena Bay at the end of the first growing season is approximately 2 mm in length. At any given age, littleneck clams from Galena Bay are smaller than those from British Columbia. In Galena Bay 8 yr are needed for P. staminea to reach a length of 30 mm as compared to 3 yr for individuals from British Columbia.

In Galena Bay the intertidal distribution of P. staminea generally follows a bell-shaped curve with upper and lower extremes occurring between the tidal heights of +0.73 and -0.76 m. The young-of-the-year are essentially epifaunal, and the majority of the specimens of all age classes are found with 4 cm of the sediment surface.

The number of individuals surviving annual recruitment into the populations studied was variable.

#### Author's Abstract

Quayle, D.B. 1964. Distribution of introduced marine Mollusca in British Columbia waters. Fisheries Research Board of Canada, Journal, 21(5): 115-1181.

The distribution of a number of species of lamellibranchs and gastropods that have been introduced into British Columbia waters largely as a result of oyster cultural operations is discussed. The dispersal routes and barriers are indicated in relation to known hydrographic conditions and circulation patterns. The problems of spawning, larval movements, metamorphosis, and spat survival are examined.

The introduced species that are discussed are Crassostrea gigas, Mya arenaria, Venerupis japonica, Ocenebra japonica, Teredo navalis, Nassarius obsoletus, Purpura clavigera, Urosalpinx cinerea, and Batillaria cumingi.

#### Author's Abstract

Quayle, D.B. and N. Bourne. 1972. The clam fisheries of British Columbia. Fisheries Research Board of Canada, Bulletin, 179: 1-70.

Annual clam landings in British Columbia are not extensive, but the fishery is important to many communities along the coast. Since 1900, landings have fluctuated from under 1 million lb to a high of about 8 million lb in 1938; the value has varied from \$10,000 to \$220,000. In recent years landings have declined.

Four clam species are exploited commercially. The butter clam (Saxidomus giganteus) is the most important and most research has been done on this species. The biology is described in some detail and serves as a model of the life history of the other species. Fishery methods described include standard fork digging as well as newer types of mechanical digging and their applicability to British Columbia clam beaches. Productivity of clam beds is discussed and estimates of annual sustained yields are given. The history of the fishery, the uses to which clams are put, clam farming possibilities, and regulations are also discussed.

Two species of littleneck clams, the native (Protothaca staminea) and the exotic Manila (Venerupis japonica), are discussed. These occur in habitats slightly different from the butter clam and from each other. The fisheries for the two species are similar and are centered mainly in the Strait of Georgia. Both species are used fresh for steaming and enter the United States Pacific coast market.

The fourth commercial species is the razor clam (Siliqua patula), that occurs only on surf-swept open sand beaches in contrast to the protected sand-gravel habitat of the other three species. A different digging technique is required since each clam is dug individually. The only commercial population is near Masset in the Queen Charlotte Islands.

Other species with future potential such as the cockle (Clinocardium nuttalli), horse clam (Tresus capax), soft-shell clam (Mya arenaria), bay mussel (Mytilus edulis), and sea mussel (Mytilus californianus), are mentioned briefly.

Results of 1960 and 1961 surveys to assess deepwater clam resources in British Columbia are presented. These surveys contributed extensively to our knowledge of the distribution and occurrence of shallow-water invertebrates, but pointed out that no commercial quantities of deepwater clams occur in British Columbia.

The potential of the industry in British Columbia is mentioned.

Author's Abstract



MUSSEL: Mytilus edulis

Black, R. 1973. Growth rate of intertidal molluscs as indicators of unexpected incidents of pollution. Fisheries Research Board of Canada, Journal. 30(9): 1385-1388.

Shells of living mollusks contain a record of previous growth rate in the time interval between check marks is known. The check marks of Mytilus edulis and Littorina littorea are probably annual marks. Growth rates of M. edulis in 1969, the year of significant elemental pollution at Long Harbour, Newfoundland, were no different from those in preceeding or succeeding years. This sort of analysis provides a method of examining nonlethal effects of unexpected polluting events. The method must be used with caution because the effects of pollutants may be confused with effects of other variables.

Author's Abstract

Ross, J.R.P. and D. Goodman. 1974. Vertical intertidal distribution of Mytilus edulis. Velinger, 16(4): 388-395.

Examination of ecological stresses on Mytilus edulis populations in a protected intertidal zone at Point Atkinson, British Columbia (Canada), shows that several factors affect part of the vertical distribution. Adult specimens survived when transplanted 0.3 m above the highest natural occurrence of the species. This suggests that successful spat settlement and survival of developing mussels control the upper limit of the species. The lower limit of M. edulis relates to a gradual increase in predation pressure by starfish, particularly Pisaster ochraceus, which is controlled by duration of intertidal submergence and number of predators. The competitive exclusion principle is inoperative between Mytilus edulis and Balanus glandula because a large proportion of the intertidal area is cleared of both M. edulis and B. glandula by the abrasive action of logs during autumn and winter storms.

Shortened Author's Abstract

Seed, R. 1969. The ecology of Mytilus edulis L. (Lamellibranchiata) on exposed rocky shores, I. Breeding and settlement. Oecologia, 3: 277-316.

The population structure and apparently erratic distribution patterns exhibited by M. edulis on many open exposed coasts, are discussed in the light of findings relating to the breeding and settlement of this species. In the absence of previous literature concerning open coast mussels, the reproductive cycle has been described

in some detail. These mussels do contribute to the spawning stock, and in the three years from October 1964 - December 1967, the period of spawning was shown to be particularly extended. Spawning occurred mainly from early spring to late summer, though individuals could be found in the spawning condition more or less throughout the year. No marked or consistent differences in the spawning periods of mussels from different local habitats or amongst animals of different size (=age) were recorded. Sexual maturity was attained in the first year of life.

#### Modified Author's Summary

Seed, R. 1969. The ecology of Mytilus edulis L. (Lamellibranchiata) on exposed rocky shores, II. Growth and mortality. *Oecologia*, 3: 317-350.

Growth studies in Mytilus edulis L. have shown that rates vary considerably according to age, size, and environmental conditions. This may in part be attributed to its sessile habit being unable to move away from the variable external conditions.

Growth is particularly seasonal, little or none occurring during the winter. Growth rates varied considerably with a variety of environmental factors (both biotic and physical) and some of these are discussed. Variable individual growth rates, together with slow growth of the majority of animals in mixed populations, are perhaps the major factors in producing population structures typical of this species on open shores.

#### Modified Author's Summary

Thompson, R.J. and B.L. Bayne. 1974. Some relationships between growth, metabolism, and food in the mussel Mytilus edulis. *Marine Biology*, 27: 317-326.

Measurements of ingested ration, assimilated ration, and metabolic rate in Mytilus edulis L. of different sizes have been integrated to provide an estimate of energy balance, which in turn describes the physiological state of the animal. These data allow the empirical determination of growth efficiency and ration. Growth efficiency increases hyperbolically with increasing ingested ration to reach a maximum, after which efficiency decreases as ration is further increased. The optimum ration for efficient growth increases with increasing weight of the mussel; maximum growth efficiency decreases with increasing body weight.

#### Author's Abstract

## LIFE HISTORIES AND DISTRIBUTIONS OF FINFISH USED IN THE STUDY

Alverson, D.L. 1960. A study of annual and seasonal bathymetric catch patterns for commercially important groundfishes of the Pacific Northwest coast of North America. Pacific Marine Fisheries Commission, Bulletin 4. 66 pp.

Migrations of the commercially important groundfishes exploited along the Pacific Coast have been reported on by various investigators. The discussions, however, are generally confined to lateral movements defined by the results of tagging studies. Vertical migrations are only occasionally encountered in the literature. The Washington Department of Fisheries initiated a new system in 1953 designed to collect information on the geographic and the bathymetric origin of trawl-caught fishes. The system provides the needed information for analyses of catch trends and movements of bottom fish.

These data have been examined for the period 1955 through 1957 to evaluate: (1) annual and seasonal depth-catch ranges of important trawl-caught fishes; (2) timing, amplitude, and direction of indicated seasonal bathymetric movements; and (3) effects seasonal depth migrations have on the availability of groundfish to the commercial fishery.

Five Pleuronectids - English sole (Parophrys vetulus), Dover sole (Microstomus pacificus), petrale sole (Eopsetta jordani), starry flounder (Platichthys stellatus), and rock sole (Lepidopsetta bilineata) - and four roundfish - true cod (Gadus macrocephalus), lingcod (Ophiodon elongatus), sablefish (Anoplopoma fimbria), and Pacific ocean perch (Sebastes alutus) - are included in the study.

### Modified Author's Introduction

Forrester, C.R. 1969. Life history information on some groundfish species. Fisheries Research Board of Canada, Technical Report. 105, 17 pp.

This paper contains an extensive bibliography and consolidates much of the available information on the life histories of some species of groundfish. The information on each species is not complete. The manuscript does not pretend to be definitive and should be considered as only a preliminary summary of the biological information available on the groundfish species and their fishery. Those groundfish covered are: English sole, rock sole, petrale sole, butter sole, lingcod and pacific cod.

Harry, G.Y., Jr. 1959. Time of spawning, length at maturity, and fecundity of the English, petrale and Dover sole (Parophrys vetulus, Eopsetta jordani and Microstomus pacificus, respectively). Oregon Fish Commission Research Briefs. 7(1): 5-13.

As part of the otter-trawl market sampling program for bottom fish, begun in the winter of 1947-48 at Astoria, Oregon, information was gathered on the time of spawning, length at maturity, and fecundity of the English (Parophrys vetulus), petrale (Eopsetta jordani), and Dover soles (Microstomus pacificus). Samples were taken from market deliveries after the small fish had been culled out at sea, leaving mostly fish larger than the generally accepted market minimum size. (English sole 13 inches, petrale 14 inches, and Dover 14 inches.) Total lengths were taken on a cradle-type measuring board to the nearest one-half centimeter.

Hongskul, V. 1975. Fisheries Dynamics of the Northeastern Pacific Groundfish Resources. Ph.D. Thesis, University of Washington, College of Fisheries, Seattle, Washington. 284 pp.

The development and production of the otter-trawl fisheries, both domestic and foreign, in the northeastern Pacific Ocean since 1906 were reviewed. The current knowledge on the biology and population dynamics of the major groundfish species exploited by these fisheries was also summarized.

Using the catch and effort statistics of the Washington coastal trawlers, the indices of relative apparent abundance of major groundfish stocks were calculated. A new technique in estimating the catch-per-unit of effort in the multispecies fishery was presented. The resultant estimates indicate a decline in abundance of groundfish resources in recent years, particularly those of English sole, petrale sole and Pacific ocean perch. For the Pacific cod and lingcod, the fishery for these species was unstable due to variation of year class strength.

The effects of fishing on the major groundfish stocks were investigated, via the surplus-production analysis. The results in general are inconclusive due partly to lack of accurate catch and effort data as a whole. Nevertheless, the effects of fishing were evident in the cases of English sole, petrale sole, Dover sole, lingcod and Pacific ocean perch. The estimates of the maximum sustainable yield and the corresponding optimum effort for these stocks indicate that these species have been harvested at or beyond their optimum levels. No significant increase in the sustainable catch from these resources can be expected from increasing fishing intensity. The management strategies for these resources and the development of exploitation on other latent resources were discussed.

Author's Abstract

## ENGLISH SOLE (Parophrys vetulus)

Anonymous. 1961. Migrations of English sole (Parophrys vetulus) on the Pacific coast of United States. Thirteenth Annual Report, Pacific Marine Fisheries Commission, 1960. Appendix I. pp. 39-42.

The research staff of the Pacific Marine Fisheries Commission member states have instituted individual tagging projects as parts of a program of stock identification. This report concerns the findings of these tagging projects. No attempt has been made to compensate for fishing effort. This is simply a record of the movement of tagged individuals from tagging areas. The returns have been grouped by quarterly periods, regardless of year, and by general area of recovery.

### Shortened Author's Introduction

Ehrhardt, N.M. 1973. Population dynamics of English sole (Parophrys vetulus) off the coast of Washington. University of Washington, NORFISH Tech. Rep. 43. 177 pp.

The English sole (Parophrys vetulus) is an important groundfish resource, and needs proper management, therefore basic knowledge about growth rates, mortality and dispersion is necessary. The present study attempts to elucidate some of the problems in stock assessment previously encountered. From Washington State Department of Fisheries tagging data an effective unit of fishing effort was developed and dispersion and population parameters were estimated. This information was in turn used to assess changes in equilibrium yield per recruit corresponding to changes in fishing mortality, and the probable status of the fishery.

el-Sayed, S.Z. 1959. Population dynamics of English sole (Parophrys vetulus Girard) in Puget Sound, Washington, with special reference to the problems of sampling. Ph.D. Thesis, University of Washington, College of Fisheries, Seattle, Washington; 189 pp.

The investigation of an isolated population of the English sole (Parophrys vetulus) in the northern part of Puget Sound, Washington, was undertaken to determine the nature of the factors which control the productivity of such a stock of fish. The factors studied during this investigation were growth, natural mortality and fishing mortality.

As to the determination of the rate of growth, the study of the effect of mesh selection indicated that no one mesh size can adequately describe the growth rate of the fish and that a series of cod-end meshes were necessary if a more representative growth curve of the population

was to be obtained. Seasonal and annual rates of growth of fish were determined and variations of growth from year to year examined. Total mortality rates were obtained from the age-frequency curves, and no major fluctuations in the strength of the year classes was evident in the samples taken between 1953 and 1956, inclusive. A mathematical model of the P. vetulus fishery was constructed in order to assess the changes in the equilibrium yield corresponding to changes in fishing mortality and age recruitment under the simplest conditions of constant parameters. P. vetulus is apparently not overfished.

#### Shortened Author's Abstract

English, T.S. 1967. Preliminary assessment of the English sole in Port Gardner, Washington. Journal of Water Pollution Control Federation. 39(8): 1337-1350.

Port Gardner receives the effluent of two pulp and paper mills and supports a valuable commercial fishery for English sole. A small research trawl was used to sample depths from 15 to 360 ft (5 to 120 m) near the deep-diffuser outfall installed in 1951. English sole dominated both research and commercial catches.

English sole were observed as planktonic eggs, young-of-the-year in shallow water, older age groups in deeper water, and in spawning condition; the eggs, planktonic larvae, and the youngest bottom stages were not sampled adequately, and future work is required.

The size distribution of English sole in a trawl catch is shown to be influenced by depth, season, and the mesh size of the net: smaller fish are in shallower water and larger fish tend to be in deeper water; the modal length of young-of-the-year and yearling fish increases during the growing season.

#### Modified Author's Summary

Forrester, C.R. 1969. Results of English sole tagging in British Columbia waters. Pacific Marine Fisheries Commission, Bulletin. 7: 1-10.

Between 1943 and 1961, over 25,000 English sole or lemon sole (Parophrys vetulus) were tagged in Canadian waters as part of the Fisheries Research Board's program to obtain knowledge of the biology of several important species which contribute to the otter-trawl fishery. This report summarizes information on movements as indicated by tag recaptures and endeavours to answer questions on the identity of stocks and directive factors in migration.

#### Shortened Author's Introduction

Holland, G.A. 1969. Age, growth and mortality of races of English sole (Parophrys vetulus) in Puget Sound, Washington. Pacific Marine Fisheries Commission, Bulletin. 7: 35-50.

This study was largely confined to two areas, Carr Inlet in southern Puget Sound and off Golden Gardens beach in Shilshole Bay, within the Seattle city limits. A limited study was made of English sole obtained from Case Inlet, which is separated from Carr Inlet by a long peninsula and is also well within lower Puget Sound. One of the objectives of this investigation was to determine if a differential growth rate existed in Carr Inlet because of population density. Another objective was to determine if the Carr Inlet population were a distinct race and could be distinguished from the others on the basis of meristic counts, morphological measurements, and tagging experiments. Possible differential rates of natural mortality were determined on the basis of random samples of age groups from each area.

#### Modified Author's Introduction

Holland, G.A. 1954. A preliminary study of the populations of English sole (Parophrys vetulus) in Carr Inlet and other localities in Puget Sound. M.S. Thesis, University of Washington, College of Fisheries, 139 pp.

This study of the age and growth of the English sole was largely confined to Carr Inlet in southern Puget Sound and Golden Gardens beach in Shilshole Bay, within the Seattle city limits. Limited studies were also made of English sole from Case Inlet, adjacent to Carr Inlet, and Port Madison, across a deep basin from Shilshole Bay. An attempt was made to determine the presence of separate races of English sole through meristic counts and morphological measurements and to determine if different mean rates of growth of the fish was demonstrable in the presumable separate populations. Statistical differences in dorsal and anal fin ray counts were found, and the observed rate of growth was approximately the same in all four sample areas.

Pattie, B.H. 1969. Dispersal of English sole, Parophrys vetulus, tagged off the Washington coast in 1956. Pacific Marine Fisheries Commission, Bulletin. 7: 11-14.

In an attempt to define the migration and distribution patterns of a commercially important concentration of English sole along the northern Washington coast, a total of 862 fish were tagged between LaPush and Destruction Island. The tagging was done during a 10-day period, between July 23 and August 1, 1956. A total of 85 English sole or 9.9% of the fish tagged was recovered over a 6-year period following tagging. Recoveries exhibited a southerly movement during the winter months. No migrations were noted north of the general tagging area.

#### Author's Abstract

Pruter, A.T. and R. Van Cleve. 1954. A preliminary study of the population of English sole (Parophrys vetulus) in Holmes Harbor, Washington. Washington State Department Fisheries, Fisheries Research Paper. 1(2): 3-18.

A preliminary study of the population of Parophrys vetulus in Holmes Harbor, Washington, was made in the winter of 1952-53. Tagging occurred between December 26 and 31, 1952 and tags recovered between January 1 and February 13, 1953. Estimates on the population size at the time of tagging was made, both uncorrected estimates for errors due to emigration or immigration and with the corrections based on tag recoveries outside Holmes Harbor.

Van Cleve, R. and S.Z. el-Sayed. 1969. Age, growth, and productivity of an English sole (Parophrys vetulus) population in Puget Sound, Washington. Pacific Marine Fisheries Commission, Bulletin. 7: 52-71.

In this investigation a total of 58,890 fish of both sexes were measured for length and identified by sex, some were aged as well. Fish were taken in Carr Inlet to compare the growth rate of Parophrys vetulus in southern Puget Sound with those in northern Puget Sound. Growth of the "zero" age-group was also studied from a series of samples from beach seines at Golden Gardens in Seattle. Mortality rates were also computed from the age distributions.

Zebold, S.L. 1970. Inter and intraspecific comparisons of the diel distributions and the food and feeding habits of demersal fishes from Duwamish Head, Puget Sound, Washington, Seattle. M.S. Thesis, University of Washington, College of Fisheries, Seattle, 76 pp.

In this study, the differences in the diel distributions, and the food and feeding habits of five species and a total of 18 classes within Parophrys, Lepidopsetta, and Chitonotus were examined. The differences in food habits are probably the best indicators of niche specialization. The diel distributions and feeding habits serve to support or amplify the results of the food study.



DOVER SOLE (Microstomus pacificus)

Demory, R.L. 1968. Age-length-frequency distributions of Dover sole (Microstomus pacificus) landed in Oregon in 1948 and 1951-65 from PMFC area 2D. Fish Commission of Oregon, Investigation Report. No. 7, 35 pp.

This report presents data collected on age-length-frequency distributions of Dover sole, Microstomus pacificus, landed in Oregon, near Astoria. The data cover only the period from June through September of each year. Age determinations for years 1948 and 1951-56 were made from otoliths. Age determinations for years 1957-65 were from scales.

Demory, R.L. and H.A. Bailey. 1967. Length-frequency and age-length-frequency distribution for Dover sole, petrale sole, and Pacific ocean perch landed in Oregon, 1948-65. Fish Commission of Oregon, Invest. Rept. No. 6. 53 pp.

A market sampling program was started in 1948 by the Oregon Fish Commission to collect biological data from certain bottomfish species. Dover sole (Microstomus pacificus), English sole (Parophrys vetulus), and petrale sole (Eopsetta jordani) were selected because of their importance in bottomfish landings. In late 1950 a similar program was undertaken of Pacific ocean perch (Sebastes alutus).

Included in this report are length-frequency and, in some cases, age-length-frequency distributions for English sole and petrale sole and Pacific ocean perch. Length-frequency distributions only are presented for Dover sole.

Hagerman, F.B. 1952. The biology of the Dover sole, Microstomus pacificus (Lockington). California Department Fish and Game, Fish Bulletin 85, 48 pp.

Facts on the biology of the Dover sole, Microstomus pacificus, are presented, as well as data on the trawl fishery it partially supports. Dover sole are found in deeper waters than the other flatfishes, and frequent muddy bottoms. There is a seasonal migration into deep water over the winter months, and in the summer large catches are taken in shallow depths of 100 fathoms or less.

Age and rate of growth were determined both by scales and otoliths, males maturing earlier than the females. Stomach contents reveal that the Dover sole feeds only on invertebrates, mainly mud inhabiting sedentary forms. Changes of survival seem better for the Dover sole than the other flatfishes because of its migrations, larger escapement size, and separate nursery areas.

Author's Summary

Mearns, A.J. and L. Harris. 1975. Growth in normal and diseased Dover sole populations. Coastal Water Research Project Annual Report - 1975, Southern California Coastal Water Research Project. pp. 43-46.

To evaluate the health of local populations of Dover sole and to gain insight into the development of the fin erosion disease, we looked at the growth and condition of individuals from a number of southern California localities. Data taken over the past few years indicate that, with some notable exceptions southern California is not a particularly hospitable region for growth and reproduction of Dover sole, even though the species is common along our coast. Fish from a number of local sites were examined to determine age, length, sex, body weight, and liver weight. These data were used to compare growth among southern California localities and between local sites and areas in central and northern California and Oregon. Age was determined by counting the number of translucent rings in the left otolith.

Westrheim, S.J. and A.R. Morgan. 1963. Results from tagging a spawning stock of Dover sole, Microstomus pacificus. Pacific Marine Fisheries Commission Bulletin, 6: 13-21.

Oregon trawlers have been utilizing availability of Dover sole on inshore grounds in summer months and discovered a concentration of Dover sole off Willapa Bay, Washington, in 180-280 fathoms. Fishing ensued and continued from October to April when the fish disappeared from the area. They returned the following year. Controversy immediately arose as to the desirability of fishing this winter stock, particularly if it was the same as the summer stock inshore. Therefore, this report deals with such a study of tagging Dover sole.

## PETRALE SOLE (Eopsetta jordani)

Alverson, D.S. and B.M. Chatwin. 1957. Results from tagging experiments on a spawning stock of petrale sole, Eopsetta jordani (Lockington). Fisheries Research Board of Canada, Journal. 14(6): 953-974.

A review is made of the historical development of the petrale sole (Eopsetta jordani) fishery off the State of Washington (U.S.A.) and British Columbia (Canada), with statistical records of catches. A shift in recent years in the depth of trawl fishing from shallow water over the continental shelf to deeper water on the continental slope resulted in the discovery of dense concentrations of petrale sole at depths from 170-250 fathoms off the west coast of Vancouver Island. Tagging was carried out in the early spring of 1954 and 1955 on these deep-water stocks. Recoveries to May 30, 1956, from some 3,800 tags released showed that the male segment of the stock moved north and inshore along the Vancouver Island coast after spawning and at least part of the stock moved eventually in Hecate Strait, British Columbia. The tagged population contributed mainly to the fisheries adjacent to the northwest coast of Vancouver Island and in the Queen Charlotte Sound area. Subsequent recoveries from the Esteban Deep during the spawning seasons of 1955 and 1956 and the absence of the stock on this ground at other seasons, strongly suggest a homing tendency for this species. A discussion is given of the possible directive factors in the spawning migration. However, at the present time the actual factors involved remain unknown.

### Author's Abstract

Didonato, G. and N. Pasquale. 1970. Migration patterns of petrale sole (Eopsetta jordani) tagged in deep water off the Washington coast. Washington Department of Fisheries, Fisheries Research Papers, 3(2): 53-62.

It's evident that the Willapa Deep petrale sole spawning population contributes to the summer inshore fishery along the Washington coast and various grounds off the lower west coast of Vancouver Island. The petrale sole inhabiting deep-water spawning areas off the Washington coast are distributed over continental shelf waters of the Washington coast and west coast of Vancouver Island. During the spring, summer, and fall months these fish appear separate from the Esteban Deep spawning population to the north and from spawning populations to the south off Oregon and California. Geographic range overlap (and mixing of stocks) does occur, however, between fish from various spawning deeps during the summer months when fish are inshore along the continental shelf. Evidence of no detectable differences in size or sex ratios between offshore and inshore petrale sole tag recoveries indicates that after spawning both sexes migrate inshore and contribute to the summer fisheries.

### Author's Conclusion

Ketchen, K.S. and C.R. Forrester. 1966. Population dynamics of the petrale sole, Eopsetta jordani, in waters off western Canada. Fisheries Research Board of Canada, Bulletin No. 153, 195 pp.

The petrale sole is an important contributor to the trawl fishery along the west coast of North America. Results of tagging suggest that there are two main units of stock in British Columbia waters, one off southern Vancouver Island and the other to the northward, mainly in Queen Charlotte Sound and Hecate Strait. Sharp reduction in abundance occurred in both stocks after the inception of fishing. Paralleling classical examples, average size and age decreased in catches from the southern stock until 1947, but this trend was reversed between 1948 and 1955 and accompanied a continued decline in abundance. Timing of the rising trend in size and age composition was the same in both the southern and northern stocks, though the histories of exploitation were different, thus indicating trends in recruitment. Year-classes of 1940-1943 contributed strongly to the fishery, but succeeding year-classes to 1949 were progressively weaker. Thereafter, there was some recovery, and early performance of the 1958 year-class suggests that it is of about the same size as those of the early 1940s.

#### Shortened Author's Abstract

Pacific Marine Fisheries Commission. 1961. Coastal movements of petrale sole as determined from tag recoveries. Pacific Marine Fisheries Commission, 13th Annual Report for the year 1960, pp. 43-44.

Nearly all experiments have been designed to determine the distribution of selected stocks of petrale sole, and many times only small numbers of tagged fish were released and few recoveries were made. This report deals with five experiments of tagging of petrale sole with fairly large numbers of releases or recoveries or both.

Pederson, M.G. 1975. Movements and growth of petrale sole (Eopsetta jordani) tagged off Washington and southwest Vancouver Island. Fisheries Research Board of Canada, Journal, 32(11): 2169-2177.

Tagging studies indicate that spawning groups of petrale sole (Eopsetta jordani) from Cape Flattery Spit Deep and Willapa Deep were the most significant contributors to the summer inshore fishery for petrale sole off Washington and Vancouver Island. Spawning groups south of Willapa Deep contributed less than 5% to this fishery. The Willapa Deep group was estimated to be at least as large as the Cape Flattery Spit Deep, although the latter supported a much larger winter fishery. Fish tagged during winter on Cape Flattery Spit Deep ranged primarily from Esteban Point south to Quillayute during summer. Ninety-seven percent of the winter recoveries from tag releases in deepwater spawning areas were made in the area of release.

Length composition data suggested that after spawning offshore, adult sole returned to inshore grounds during the summer.

For mature sole, growth parameters estimated from tagged fish agreed with those calculated by other methods of ageing.

## CURRENT BIBLIOGRAPHIES AND LITERATURE REVIEWS

Anderson, J.W., J.M. Neff, S.R. Petrocelli, M.A.Q. Khan and J.P. Bederka, Jr. (ed.). 1974. Sublethal effects of oil, heavy metal, and polychlorinated biphenyls on marine organisms. In: Survival in Toxic Environments. Symposium. XXI, Academic Press, N.Y., N.Y., pp. 83-121.

This review described what has been and is now being done in the study of the sublethal effects of three major classes of pollutants commonly found in the estuarine environment. The material presented indicates that there is still a great deal of baseline information on the "normal" responses and functions of marine and estuarine species needed before the effects of pollutants on these parameters can be assessed fully. Furthermore, physiological parameters and the effects of pollutants on them are greatly complicated by natural factors such as season of the year, condition of the animal, its sex, its life stage and countless other variables. Therefore, in any assessment of sublethal effects of pollutants, the biology of the organism under investigation must be well understood.

### Modified Author's Discussion

Anonymous. 1970. Mercury contamination in the natural environment. A cooperative bibliography. U.S. Department of the Interior, Office of Library Services, Washington, D.C., 32 pp.

Environmental contamination by mercury is a current concern of many bureaus and offices of the U.S. Department of the Interior. The purpose of this bibliography is to provide access to the literature related to this subject for those people who are now beginning to work on the problem.

### Shortened Author's Preface

Anonymous. 1972. Mercury in water-a bibliography. U.S. Office of Water Resources Research, Washington, D.C., Water Research Scientific Information Center, WRSIC 72-214.

This is a compilation of 195 abstracts for selected reports, journal articles, and various documents published mostly since 1967 on mercury in water. The abstracts include full bibliographical citations and a set of descriptors from the Water Resources Thesaurus.

Battelle's Columbus Laboratories. 1971. Effects of chemicals on aquatic life. Selected data from the literature through 1968. For the Environmental Protection Agency, Research and Monitoring, May 1971, In: Water Quality Criteria Data Book - Vol. 3.

Original data from more than 500 technical publications concerning the specific effects of chemicals on individual species of aquatic biota were collected and summarized in uniform format. Alphabetical assembly of the data by chemical allows rapid access to considerable detailed information. A Species Index facilitates search for information on the toxicity of chemicals to individual aquatic species.

The details of major procedures in laboratory bioassay and field assessment of chemical toxicity in water are discussed, and freshwater and marine procedures are included. A total of approximately 1,000 references were utilized in preparing this report.

#### Shortened Author's Abstract

Chapman, G. 1973. Effect of heavy metals on fish. In: Heavy Metals in the Environment; Proceedings, Seminar at Oregon State University, Corvallis, Oregon, 1972: available from Oregon State University, Water Resources Research Inst. Report. SEMN WR 016. 73: 141-162.

A review of literature with respect to the toxicity to freshwater fish of zinc, copper, and cadmium, showed a wide range of LC-50 (96 hr) values. For zinc this range was 90 to 40,900 ug/l; for copper 46 to 10,000 ug/l; and for cadmium 470 to 9,000 ug/l. Two general conclusions are that toxicity varies inversely with hardness, and that salmonids (trout and salmon) are more susceptible than most other common freshwater teleosts. Disregarding species and age, all other generally recognized factors which influence toxicity of heavy metals to fish do so by influencing rate of accumulation of metal and, primarily, rate of uptake. Thus pH, hardness and alkalinity, temperature, and dissolved oxygen content influence rate of uptake of the metal by changing either the biological availability of the metal by altering its form or by altering the rate and volume of ventilation of the fish.

Collias, E.E. 1970. Index to physical and chemical data of Puget Sound and its approaches, 1932-1966. Washington Sea Grant Publication, University of Washington, Seattle, WSG 70-4, 823 pp.

The purpose of this index to physical and chemical data of Puget Sound and its approaches are (1) to provide a convenient and rapid reference to the majority of locations where water samples were collected for various physical and chemical determinations between the years 1932 and 1966, (2) to provide a listing of the type of data taken, and (3) to reference the sources from which these data may be obtained.

Collias, E.E. and A.C. Duxbury. 1971. Bibliography of literature: Puget Sound Marine Environment. Washington Sea Grant Program, University of Washington, Seattle, WSG 71-6, 1059 pp.

This work presents an annotated bibliography covering geography, climatology, hydrology, geology, volcanology, seismology, geomagnetism, geodesy, hydrography, physical oceanography, and marine biology of Puget Sound and its adjacent land areas.

Day, D. and C.R. Forrester. 1971. A preliminary bibliography on the trawl fishery and groundfish of the Pacific coast of North America. Fisheries Research Board of Canada, Technical Report No. 246.

The need for a bibliography on the trawl fishery and groundfish of the west coast of North America has become increasingly obvious to groundfish workers. This is a preliminary list hopefully of value to groundfish workers on the Pacific coast. Most of the references included are confined to work done on the Pacific coast even though many of the species also occur in Atlantic waters.

Doudoroff, P. and M. Katz. 1953. Industrial Wastes: Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals, as salts. Sewage and Industrial Wastes, 25: 802-839.

Most of the metal compounds here are those simple inorganic salts, the toxicity of which is evidently referable chiefly to the component metals. Comparative studies of the toxicity of different metals the factors which account for variations of their toxicity are also considered. The metals are then discussed individually.

Eisler, R. and M. Wapner. 1975. Second Annotated Bibliography on Biological Effects on Metals in Aquatic Environments. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Lab., Ecological Research Series. EPA-600/3-75-008.

A total of 725 references are listed on the toxicological, physiological, and metabolic influence of stable and radiolabeled chemical species of metal cations to marine, estuarine, and freshwater fauna and flora. References were annotated and subsequently indexed by metal, by taxa, and by author, in cumulative indices which encompass this volume and the initial volume in this series (Eisler, R., 1973).

Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments. U.S. Environmental Protection Agency Report EPA-R3-007: 1-287.

A total of 567 references on biological effects of metals to aquatic organisms were annotated and subsequently indexed by metal and by taxa. Preference was given to articles on toxicity of heavy metals to marine, estuarine, and anadromous species.

Author's Abstract

Ellinger, Elaine and George Snyder. 1975. An annotated bibliography of the effects of dredging and dredge disposal on aquatic organisms in the Pacific Northwest with selected references on biological studies of the lower Columbia River and on related dredge and disposal studies. Completion Report for U.S. Army Corps of Engineers, Dredged Material Research Program. By Environmental Conservation Division, Northwest Fisheries Center, Seattle.

This bibliography was prepared in conjunction with studies by the National Marine Fisheries Service on channel maintenance dredging and habitat creation in the Columbia River Estuary. Although much literature on dredging deals with negative impact of disposal of polluted and/or fine-grained spoil, Columbia River dredge spoils are generally clean and sandy. Some of the dredging studies in the annotated section of the bibliography concern polluted dredged areas; other related studies are included in the supplementary reference list.

#### Shortened Author's Introduction

Ferens, M.C. 1974. A review of the physiological impact of mercurials. Office of Research and Development, U.S. Environmental Protection Agency, EPA-660/3-73-022.

Literature on the biological effects of mercurials was reviewed with the purpose of understanding impact on individual organisms in terms of biochemical or cellular damage. Mercurialism is manifested primarily in kidney or brain damage in animals and in growth reduction in plants. Exposure to inorganic mercury compounds usually results in kidney damage while alkyl mercurialism is characterized by brain damage; however, some degree of both kidney and neurological injury results from exposure to either category of mercurials. Kidney injury is due apparently to damage of Krebs's cycle enzymes, thus reducing available energy to actively resorb ions. Impaired protein synthesis as well as reduction in activity of Krebs's cycle enzymes may be important in brain damage resulting from mercury poisoning. Photosynthetic damage is apparently the biochemical basis for mercurial effects observed in plants.

#### Shortened Author's Abstract



Flick, D.F., H.F. Kraybill and J.M. Dimitroff. Toxic effects of Cadmium:  
A review. Environmental Research, 4(2): 71-85.

A review has been made of current knowledge, published and unpublished, relating to cadmium toxicity. The survey included worldwide epidemiology of the metal, distribution pattern in our environment, industrial production and uses, modes of incorporation into the human body, and possible significance of the metal with respect to metabolism.

The findings revealed that cadmium is virtually ubiquitous, not only being deposited and accumulated in various body tissues, but found in varying concentrations throughout all environmental compartments (air, soil, food, and water) in which man must live. It appears that within the past two decades there has been increased industrial production and use of the metal. Concomitantly, there has been an increased incidence of both acute and chronic cases of clinically identifiable cadmiosis.

Experimental evidence obtained under controlled laboratory conditions suggests that cadmium may function in or may be an etiological factor for various pathological processes including testicular tumors, renal dysfunction, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age, and cancer. In addition, it was reported that cadmium may result in hemorrhagic lesions in sensory ganglia within the central nervous system. A number of investigators found some toxic aspects of exogenously administered cadmium to be partially or even totally prevented by zinc, cobalt, selenium, estrogen, British antilewisite (BAL) and thiol compounds.

#### Author's Abstract

Friberg, L., M. Piscator and G. Nordberg. 1972. Cadmium in the environment. The Chemical Rubber Co., Cleveland, Ohio., 166 pp.

The second edition of Cadmium in the Environment presents and in some cases reevaluates all information contained in the first edition, in the second EPA report, and subsequent findings, published as well as unpublished, up to and including part of 1973. The present work focuses upon information essential to the understanding of the toxic action of cadmium and the relationship between exposure and effects on human beings and animals.

Katz, M. 1973. The effects of heavy metals on fish and aquatic organisms. International Conference on Heavy Metals in the Aquatic Environment, Vanderbilt University, Dec. 4-7, 1973.

A review of the literature concerned primarily with actual concentrations of heavy metals permissible in water without having any harmful effects.

Miettinen, J.K. 1973. The accumulation and excretion of heavy metals in organisms. International Conference in Heavy Metals in the Aquatic Environment, Vanderbilt University, Dec. 4-7, 1973.

This review is concerned mainly with mechanisms and rates of absorption and excretion of cadmium, mercury and lead with particular reference to their biological half-times and accumulation in man with treatment of fish and shellfish. Only the latest results and views are discussed.

Oregon State University. 1971. Oceanography of the nearshore/coastal waters of the Pacific Northwest relating to possible Pollution. Vol. I. For the Water Quality Office, Environmental Protection Agency, Grant No. 1607OEOK. Water Pollution Control Research Series.

This study is limited to the coastal zone of the Pacific Northwest from high tide to ten kilometers from shore, and does not include estuaries and bays. The literature has been reviewed in 21 chapters including chapters on geology, hydrology, winds, temperature and salinity, heat budget, waves, coastal currents, carbon dioxide and pH, oxygen, nutrients, and biology. Special chapters deal with field studies on thermal discharges, heat dispersion models, pulp and paper industrial wastes, trace metals, radiochemistry, pesticides and chlorine, thermal ecology, and biology of 20 selected species. A summary chapter is entitled "The nearshore coastal ecosystem: an overview." The bibliography contains more than 3100 entries, most from the open literature, but some from unpublished reports.

#### Shortened Author's Abstract

Peakall, D.B. 1972. Polychlorinated biphenyls: Occurrence and biological effects. Residue Review, 44: 1-21.

This review is concerned with the levels found in the environment for PCB's and an evaluation of toxicological and physiological effects. PCB's have been shown to be widespread in the environment. The levels found tend to parallel total DDT in concentration and PCB's are frequently the dominant organochlorine compounds known to be present. Since PCB's are highly stable, they can be expected to persist in the environment for many years. The acute toxicity of PCB's is low although impurities such as the chlorinated dibenzofurans are highly toxic. Preliminary results suggest that PCB's are embryotoxic in the ten ppm range in the diet.

Risebrough, R.W. and B. DeLappe. 1972. Accumulation of polychlorinated biphenyls in ecosystems. Conference on PCBs., Papers. (Held in Rougemont, N.C., Dec. 20-21, 1971). In: Environmental Health Perspectives, Experimental Issue No. 1: 39-45.

In this paper some of the available residue data are summarized within the framework of a preliminary formulation of a mass balance equation for the global distribution of polychlorinated biphenyls.

Sandeman, E.J. 1971. Canadian Research Programs. In: Proceedings Conference on the Canadian shrimp fishery. Canadian Fisheries Reports, No. 17, pp. 25-29.

This paper presents a brief review of Canadian research programs on the biology of the pink shrimp or great northern prawn, Pandalus borealis. The objectives of future research and some of the methods and priorities that might be applied to achieve these objectives are enumerated.

Scrivener, J.C. and T.H. Butler. 1971. A bibliography of shrimps of the family Pandalidae, emphasizing economically important species of the genus Pandalus. Fisheries Research Board of Canada, Technical Report 241, 42 pp.

Research on commercially important pandalid shrimp populations has been conducted on the genus Pandalus, but some literature on remaining genera is also included. The bibliography contains 458 references, annotated by species, geographical areas and subject.

Shaw, J.T. and S. Schott. 1974. A Compendium of Current Environmental Studies in Puget Sound and Northwest Estuarine Waters. Oceanographic Institute of Washington.

The primary result of the initiation of this Current Environmental Studies program by the Oceanographic Institute of Washington was the compilation of this document. It is a descriptive record of many of the marine environmental studies and research programs that were in progress in the area during the calendar year 1974.

Steinberg, M.A. 1972. A review of some effects of contaminants on marine organisms. Indo-Pac. Fish Council. Proc., 15(2): 8-23.

The effects of some pesticides, PCB's, heavy metals, solids and petroleum products on aquatic organisms are reviewed. The need to understand the mode of action of these toxicants on biological systems as well as the possible synergistic effects of pollutants on single species and entire ecosystems is stressed. The significance of exposure to sub-lethal doses of pollutants in respect to the safe-guarding of aquatic resources is considered and the development of proper experimental design in this field of research are considered.

#### Author's Abstract

Veith, G.D. and G.F. Lee. 1970. A review of chlorinated biphenyl contamination in natural waters. Water Research, 4(4): 265-269.

A review of the present state of knowledge concerning environmental contamination by organochlorine compounds indicates that the chlorinated biphenyls may be one of the more widespread contaminants. The significance of this contamination has not yet been evaluated due, in part, to the lack of systematic analytic procedures for the quantitative and qualitative determinations of the components of chlorinated biphenyl mixtures. The possibility of the chlorinated biphenyls producing serious errors in chlorinated pesticide analyses is emphasized.

#### Author's Abstract

Water Resources Scientific Information Center. 1973. Cadmium in water - a bibliography. U.S. Department of the Interior, Office of Water Resources, WRSIC - 73-209. 231 pp.

"Cadmium in Water" is one of several bibliographies from the U.S. Department of the Interior in water resources. These bibliographies are produced from the information base of Selected Water Resources Abstracts (SWRA) only.

Water Resources Scientific Information Center. 1975. Mercury in Water, Volume 2. Office of Water Research and Technology, U.S. Department of the Interior, 307 pp.

This bibliography follows in a series of planned bibliographies in water resources to be produced from the information base comprising the Selected Water Resources Abstracts (SWRA). The first volume, issued in 1972 covered the material from 1968 to 1971, and volume 2 covers the period from 1972 to February 15, 1975.

#### Author's Introduction

Water Resources Scientific Information Center. 1973. PCB in water - a bibliography. U.S. Department of the Interior, Office of Water Resources Research, WRSIC - 73-201.

"PCB in Water" is another in a series of planned bibliographies in water resources to be produced wholly from the information base comprising only Selected Water Resources Abstracts (SWRA). This bibliography covers through December 15, 1972.

#### Author's Introduction

Zitko, V. and P.M.K. Choi. 1971. PCB and other industrial halogenated hydrocarbons in the environment. Fisheries Research Board of Canada, Technical Report No. 272.

Industrial applications of polychlorinated biphenyls (PCB), chlorinated naphthalenes, chlorinated paraffins, chlorinated benzenes, polybrominated biphenyls, chloro-bromo biphenyls, chloro-hydroxy biphenyls, and halogenated carboxylic acids are described. A list of other halogenated hydrocarbons and derivatives, used as solvents, fumigants, refrigerants, flame retardants, aerosol propellants, heat-transfer media, hydraulic fluids, etc., is included. Current methods for the measurement of PCB are reviewed. PCB and p,p'-DDE levels in fishes and aquatic birds, reported in the literature, are summarized. Recently determined PCB concentrations in Atlantic salmon, bluefin, yellowfin, and skipjack tuna, bluefish, swordfish, and blue marlin, cod, white hake, plaice, and redfish, double-crested cormorant, herring gull, black duck, and guillemot are presented. The determination of polychlorinated terphenyls (PCT) in biological samples and the behaviour of polybrominated biphenyls and polychlorinated dibenzo-p-dioxins and dibenzofurans during cleanup and gas chromatography is described. Biological effects of PCB and other halogenated hydrocarbons are reviewed. The sources of PCB leakage into the environment and their circulation are discussed. Analytical procedure for the determination of PCB and organochlorine pesticides based on the modified cleanup chromatography of Holden and Marsden is described.

Author's Abstract

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